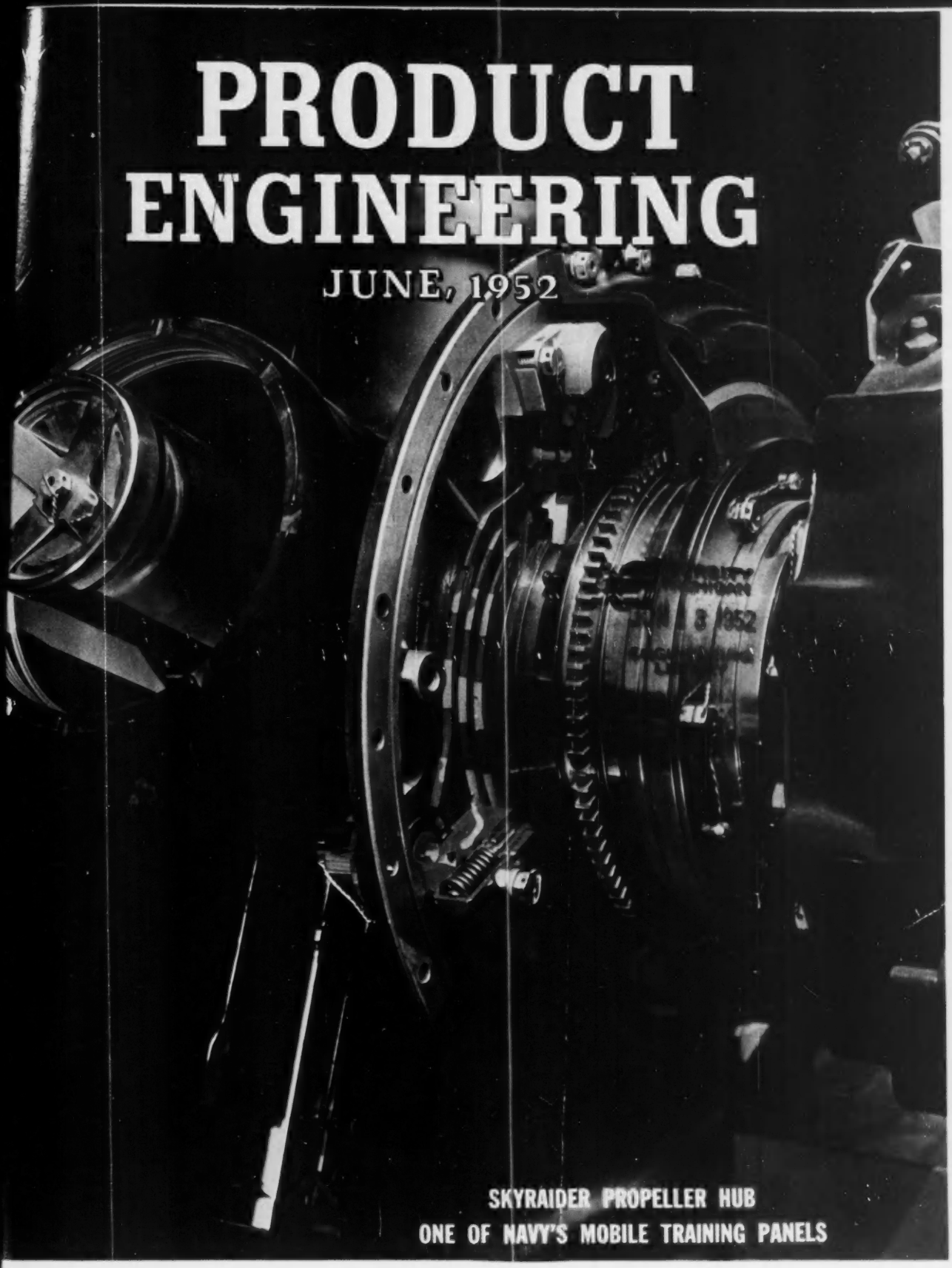
PRODUCT ENGINEERING

JUNE, 1952



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IN THIS ISSUE — Keyless Couplings ✦ High Current Rectifiers ✦ Slider Crank Mechanisms ✦ Analysis of Vibration Mounts ✦ Rectangular Springs

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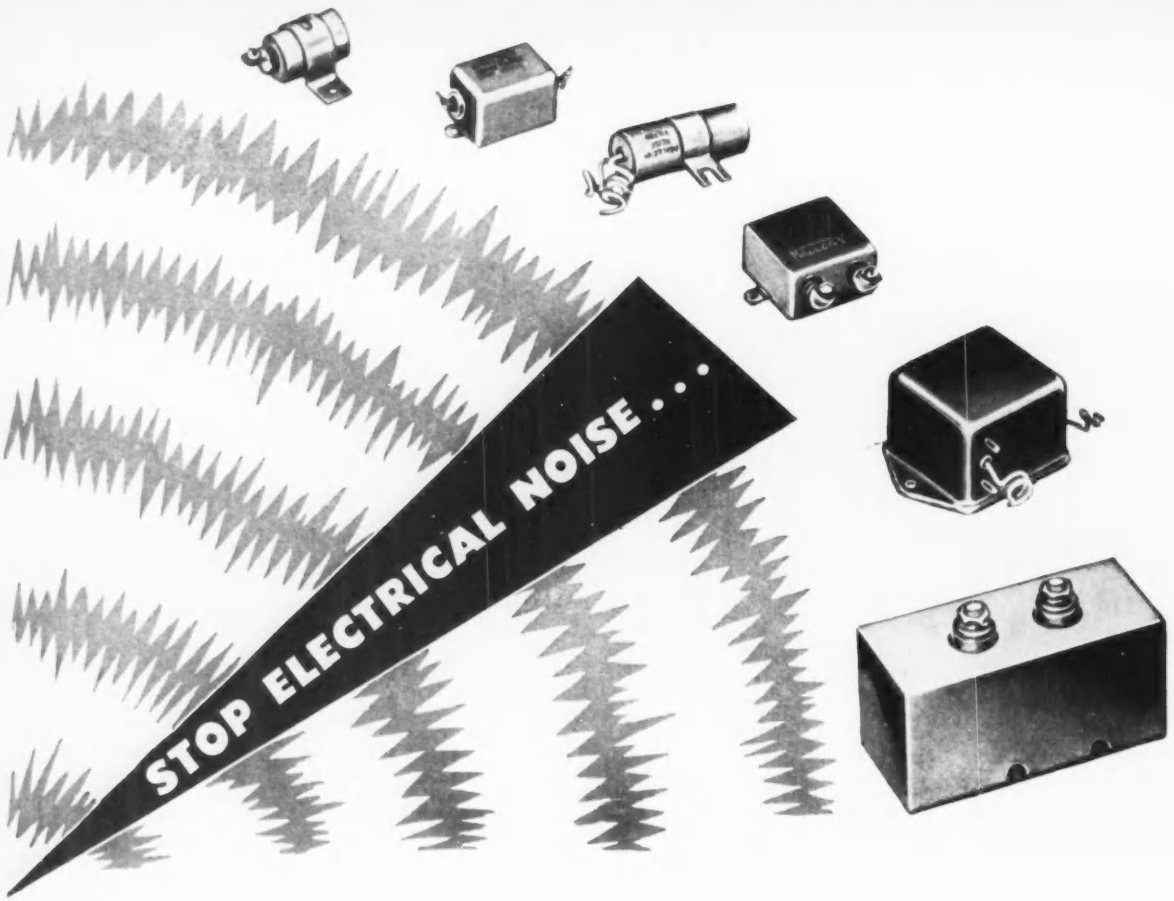

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For information on Titanium Developments contact Mallory-Sharon Titanium Corp., Niles, Ohio.

Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

OVERALL ADHESION of Dow's Styrofoam plastic to the inner surfaces of airframe controls may permit Northrop Aircraft Corp., Hawthorne, Calif. to eliminate ribs and 80 percent of the rivets. By filling voids with the expanded polystyrene, vibration is minimized, controls can be made 15 percent larger in area, weight decreased by 10 percent and strength increased by 10 percent.

TWO MORE USES for du Pont's Teflon are worthy of mention. Resistoflex Corp. of Belleville, N.J. impregnates flass fiber tubing with the fluorine derivitive to obtain a noncorrosive, yet rigid tube with wall section of only 0.030 in. Dixon Saddle Co., Bristol, R.I., molds the resin as sleeve bearings for low-speed, light-load (100-200 rpm at about 175 psi) applications. The material's low coefficient of friction obviates need for a lubricant in the bearing.

A CONTINUOUS TEMPERATURE of 1,800 F does not affect A-418 Ryanco-C ceramic coating. The developers, Ryan Aeronautical Co. of San Diego Calif. and California Metal Enameling Co., also state that thermal shocks encountered in exhaust systems between -70 and +1,700 F do not induce coating failure.

DELICATE EQUIPMENT such as instruments can be protected in shipment with a cellulose-base cushioning material developed by Gilman Brothers Co., Gilman, Conn. Called Celluliner, the product has two-thirds the resilience of pure sponge rubber and comes in various grades.

QUARTZ PAPER that can be substituted for asbestos insulation is one of the newer developments at the Naval Research Laboratory, Washington. Made from domestically abundant materials, the quartz-like fibers, stable to 3,000 F, are either hydrous or anhydrous. The latter type is expected to find use in electrical applications.

CONTACT PRESSURES and low curing temperatures describe Epon VI adhesive made by the Shell Chemical Corp. of New York City. The two-component system, consisting of a dark gray polymer paste and clear liquid curing agent, is best suited for bonding metals, but is also effective on wood, glass, plastics and rubber.

20 PERCENT LESS SWELLING in the presence of hydrocarbon fuels is the feature of 1009-10 synthetic rubber perfected by The Parker Appliance Co, Cleveland. This property is valuable for equipment designs subject to -65 F qualification where previous available compounds have been rejected for excessive swelling.

METALLIC MATERIALS

SPECIAL MATERIALS with physical and nuclear properties that satisfy purity standards heretofore unachievable on a commercial-quantity basis are needed for atomic reactors. For structural use, Oak Ridge scientists consider the more promising materials to be beryllium, titanium and zirconium; for liquid coolants, they predict bismuth, sodium, potassium or their combinations.

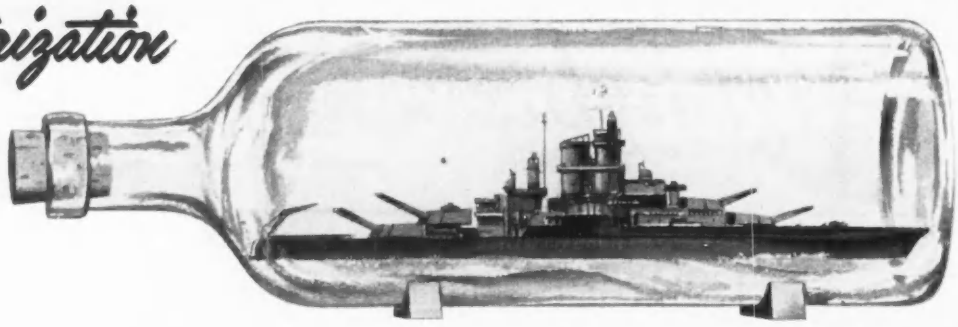
SILVER-CLAD STAINLESS is being produced at the American Cladmetals Co. in Carnegie, Pa. for use in communications equipment. Silver surface exhibits better-than-copper electrical conductivity, while the stainless steel provides corrosion resistance and a rigid backing.

RARE MINERAL, one part yellow (vanadium) and the other a pale bluish-green (copper), has been found for the first time in the West near Riverside, Calif. by a Professor at UCLA. Nasonite is a form of calcium lead silicate and is derived from earlier galena.

WHITE BRASS, 80 percent zinc and 20 percent copper, deposited from a cyanide bath either directly on cleaned steel or over a copper flash is a good substitute for nickel as a base for

(continued on page 7)

Miniaturization



Mighty Midgets in Plastics

For the newest important developments on the plastics front, look to the intensive miniaturization program underway in the electronics and communications fields. Working, in this case, through the vast resources of RCA, the program calls for intense miniaturization in size, and reduction in weight, of physical components. Idea, of course, is to produce smallest, lightest, assemblies possible–with greatly improved efficiency–for a scope of use impossible with unwieldy old equipment.

What a made-to-order spot for plastics! And for a moulder! The terminal boards, insulators, coil cases and covers (shown here actual size) have tolerances so close that in some instances, they are machined to final dimensions. There are wall sections as thin as .012". Inserts are fine Swiss screw machine plated parts with exacting thread fits assembled to microscopic dimensions. Materials are low-loss mica-filled phenolics.

There's a production story here, too! With such necessary precision, commercial production was at first thought to be impossible. Within three weeks, we produced experimental tooling and a production method using compression and plunger techniques along with a combination of the two. *And then, carefully analyzing our experimental program, we designed and produced production tooling–and are now meeting production quotas and rigid inspection with commercial moulding methods!*

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FOR OVER 36 YEARS PLANNERS AND MOULDERS IN PLASTICS

chromium. The two-coat finish is applicable with standard plating equipment, has good adherence and greater resistance to salt corrosion than conventional Cu-Ni-Cr plating, according to Knight Plating Co. of Detroit.

HEAT-TREATED AND COLD-WORKED copper-silver alloy, produced by Handy & Harman, New York City 38, has tensile strength ranging from 140,000 to 165,000 psi. Electrical conductivity is 70 percent of International Annealed Copper Standard. Composed of 94.0 percent copper and 6.0 percent silver, alloy comes as round wire from 0.260 in. dia down to magnet size and as strip.

MAGNESIUM has replaced zinc in flashlight batteries being field tested by the Army Signal Corps. The metal, used for the can-like covering, lasts twice as long, costs about the same, and should save 66,000 tons of zinc per year.

COMPONENTS

PRINTED CIRCUIT PACKS containing up to six resistors and capacitors pre-connected into a desired circuit are reported to hold almost constant ohmic values throughout the temperature range from 10 to 85 C. The Stupakoff Ceramic and Mfg. Co. of Latrobe, Pa. has assemblies with resistance from one ohm to six megohms, 0.2 to 3.0 watts with a tolerance of ± 5 percent. Capacitive values are available from 2.0 mmf to 0.04 mf with tolerance of ± 3 percent.

SPRING-ACTION CASTERS give a smooth ride to industrial equipment that passes over irregular floor surfaces. The Faultless Caster Corp., Evansville 7, Ind. is the manufacturer.

IRONCLAD BATTERIES recently perfected by Exide of Philadelphia have in the positive plate a silver alloy that reduces corrosion of the grid. Battery life is also increased by enclosing the grid in slotted rubber tubes. This lets electrolyte reach grid, but prevents alloy washout.

ELECTRONIC LIGHT AMPLIFIER invented by Lee deForest and W. A. Rhodes of Phonix, Ariz. is the subject of U.S. Patent 3,594,740. The unit receives a beam of light forming an image, transforms it into a beam of electrons, increases the intensity of the latter and then retransforms it into an intensified light beam of the image.

RECORDING READ-OUT, which converts computer impulses into understandable symbols, is a revamped TV tube. Convair's version does 10,000 characters a second. The tube's electron beam is passed through a stencil-like plate cut to letters and numbers that match the output of the computer. A converter between computer and tube changes the computer's answers into pulses that represent the characters in the plate. A Zerography print can then be made.

NEW LOOK IN FRAMES for the side windows of the 50th anniversary Nash displays polished and ribbed aluminum extrusions instead of the conventional chromium plated steel. Being narrower than standard parts, new frames increase the area of vision without enlarging window opening.

MAGNETISM powers a pump that has no moving parts. Though invented in about 1907, electromagnetic device was never put to work until the atomic age called for its use in circulating liquid-metal coolant through an atomic reactor at Argonne National Laboratory, Chicago. A magnet is built around a rectangular piece of tubing. When current is passed through the coolant, a motor-like electrical reaction takes place, forcing the liquid through the tube.

PROCESSES

VAPOR DEPOSITION of metals lends itself to continuous operation at atmospheric pressure and below-melting-point temperatures; ie, tantalum (M. P. 3,000 C) can be deposited at 500-600 C. Thicknesses of deposits vary from 0.0001 to 0.005 in., depending upon type of service of finished part. Among the applications are heat-sensitive elements, vacuum tube and photo-tube elements, transparent lenses and conductive coatings.

COMMERCIAL AND HIGH-PURITY ALUMINUM are the easiest to solder, then the alloys containing up to one percent manganese or magnesium; the heat treatable alloys are more difficult to solder, according to Reynolds Metals Co. Generally, the oxide coating is dissolved and kept from reforming by suitable fluxes, although the friction method is sometimes used. If the finished joints in small assemblies are exposed to moisture, a solder rich in tin with considerable zinc provides resistance to galvanic attack.

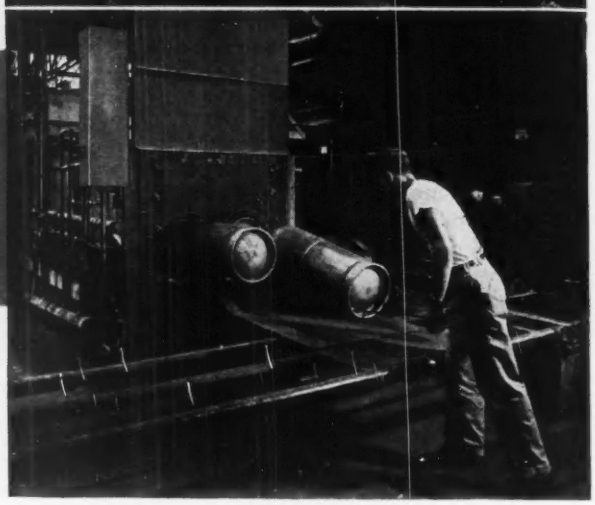
(continued on page 9)

Metallurgical furnace investigations in the laboratory influence heat processing in manufacture.

Laboratory-proved techniques

assure the

factory-made quality



of

SCAIFE

pressure vessels and deep-drawn shapes

To meet industry's ever-advancing needs for pressure vessels and deep-drawn shapes of lighter weight, higher strength, greater dependability and longer life, Scaife maintains constant research and engineering studies of materials, methods and products.

The findings of these research programs are used by Scaife engineers in the design and production of vessels to give them the qualities needed to meet the requirements of the particular service for which they are built.

The name SCAIFE on pressure vessels and deep-drawn shapes means highest quality and most advanced design.

Starting with a circular sheet of steel—
a cup is formed by a conventional drawing operation.
A continuation of this pressing operation turns the cup "inside out" without removing it from the dies,
completing—in a single stroke—the deep-drawn shape.
Deep-drawn shapes made by the Scaife reverse-draw process (described above) have uniform wall thickness throughout the entire length of the draw. Can be made in various lengths, diameters and symmetrical shapes.
Scaife cylinders are used for liquefied petroleum gases, freon, acetylene, sulfur dioxide and other materials. They are light in weight, strong and durable.
Scaife pressure vessels for air, gases and liquids are made in standard and special designs and for various types of service.

Makers of Pressure Vessels for Air, Gases and Liquids

Scaife Company

OAKMONT (PITTSBURGH DISTRICT), PA.

A NOTABLE ADVANCE in metal powder processing is said to eliminate oxidation and result in improved mixing characteristics. A spokesman for the Glidden Co., reports that fabricators of powdered metal parts will obtain, in addition to longer die life, better uniformity of part size characteristics during processing, faster and more complete alloying and decreased molding pressures.

ELECTROPLATING TECHNIQUE has been developed by Battle Memorial Institute whereby aluminum radar parts having thickness of 0.025 to 0.040 in. can be produced. Core is low-melting cadmium alloy containing 1-2 percent Ni which is copper-plated and electropolished. Bath consists of a toluene solution of the product obtained by fusing ethyl pyridinium bromide with aluminum chloride. The core is then removed by heating and the copper dissolved in nitric acid.

IN FORMING TITANIUM, it is desirable to preheat both the sheet and the dies. The softer commercially-pure titanium forms better than its alloys, and good results are obtained with metal heated to 450-600 F and dies to about 300 F. This reduces work hardening and spring back, but galling is still a problem. North American engineers have also succeeded in brazing titanium, provided the work is enclosed in a bell jar and the brazing done in an inert atmosphere.

TESTING

FLUORESCENT CHALK is a recent product of the Norco Mfg. Co., New York City 14. Material is reported to be very effective in black light, permitting illustrated slide demonstrations to take place without turning on the normal lights.

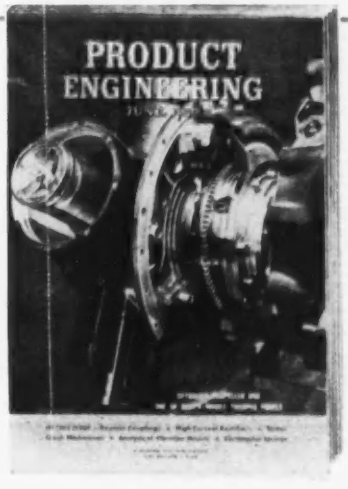
SMALL "ATOM SMASHERS" are being built and put to work. Dr. H. F. Kaiser of Naval Research Labs, Washington, recently described a microtron or miniature electron cyclotron, that operates in frequency band of 3-cm radio waves.

TINY PRESSURE TRANSDUCER designed by Statham Labs. Inc., Los Angeles, has helped advance high-speed hydrodynamic research at Convair. The 0.5-in. dia unbonded strain gage pickup, Model 81, has three ratings - 10, 30 and 100 psi absolute, and is temperature-compensated for a max error of 0.01 percent full scale per deg F from -50 to +100 F. Output will drive oscillographic galvanometers without amplifiers.

THE DEFENSE COMPUTER takes less than one-fourth the floor-space occupied by the selective sequence electronic calculator, first of the large "electronic brains" developed by I.B.M. engineers, and is "twenty-five times as fast and far more flexible".

COSMIC RAYS and Geiger tubes have been combined at Johns Hopkins Univ. in a new altimeter. Instrument has two layers of five tubes. Cosmic rays strike one layer of tubes, activate them, pass through a lead shield and energize the second layer. When both sets of tubes are triggered, a calibrated voltmeter registers altitude in feet.

ROLL SURFACE TEMPERATURES from -40 to +450 F can be measured precisely with special head made by The Foxboro Co., Foxboro, Mass. Key element is a small resistance bulb mounted in a block of Marinite that protects it from ambient air. To avoid scratching roll, element is carried by a special faceplate that wipes air from the roll, giving additional temperature control.

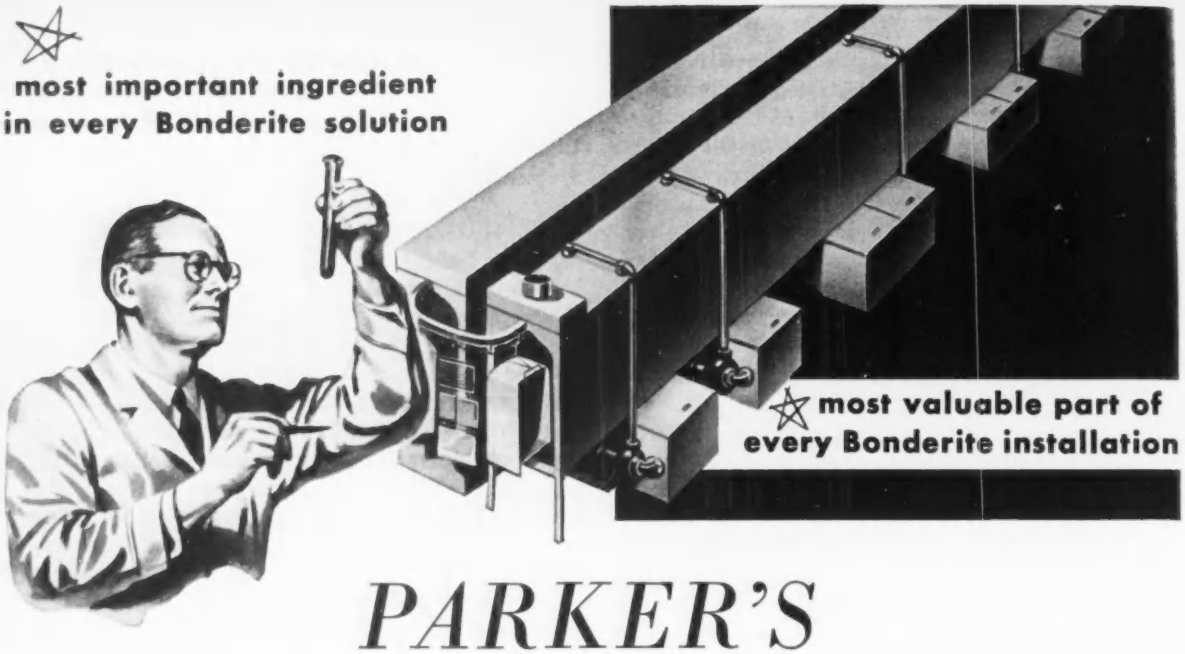


THIS MONTH'S COVER

With machines of war becoming infinitely more complex, the skill with which they are maintained and serviced may well determine their success in combat. Especially is this true of aircraft. And, of course, the better a pilot knows his plane, the easier it is to weld both into an integral fighting unit.

On this month's cover is a cutaway of the propeller hub for the Douglas Skyraider attack bomber. It, along with full scale panels of complete aircraft systems, is part of a mobile training show being used by the Navy for instruction of personnel. See page 186 for details. Kodochrome courtesy El Segundo Division of Douglas Aircraft Company.

most important ingredient in every Bonderite solution



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corrosion resistant paint base	aids in cold forming of metals	rust resistant	wear resistant for friction surfaces

Perspectives — DESIGN AND DEVELOPMENT

SHELL MOLDING

Shell molding, considered the outstanding foundry development of a generation, is still tied up in the most controversial patent tangle since the Ford Motor Company got the Selden Patents revoked in 1911. Also known as the Croning or "C" Process, this technique uses a thin mold made of phenolic resin (6 to 8 percent by weight) and sand (92 to 96 percent by weight) to cast metal parts. The exceptional interest has been aroused because it permits the casting of metal parts having intricate contours, thin sections, and very smooth surfaces in sizes larger than ever before considered practical. Precision of finished parts is such that users find machining operations are decreased up to 50 percent.

Industry is lined up on two sides of the patent battle, even though no patent has yet been issued. And litigation seems sure to go to the Supreme Court if a patent is granted. Most users claim that the process developed by Johannes Croning in Germany is booty captured during the war. And as such, it is in the public domain.

There's strong support for this argument. Croning filed a patent application for this process in Germany in 1944, but no patent was granted. U. S. Intelligence teams questioned Croning after the war and brought back the development in Department of Commerce's Office of Technical Services Report "Fiat Final Report No. 1168" dated May 30, 1947.

GOVERNMENT VIEWPOINT

Government authorities say the process belongs to the U. S. and is freely available. John C. Green, Director of OTS, said:

> "It appears that the "C" Process as known in Germany and that the information collected by McCulloch was collected in good faith for the benefit of U. S. Industry at large."
>
> "Any improvement patents arising out of postwar research are, of course, not included in the principle that captured technology is freely available."
>
> "If valid U. S. Patents are obtained on such improvements, industry would ordinarily obtain licenses to practice the invention under such patents. At this moment we are not aware of this situation since all patent applications are preserved in secrecy by the U. S. Patent Office. And neither the inventor, nor the licensee has seen fit to disclose the subject matter of the application he alleges to have filed."

While minor improvements have been made in the process by both the inventor and others, OTS feels that those they know about are only plant procedures and are not necessarily patentable.

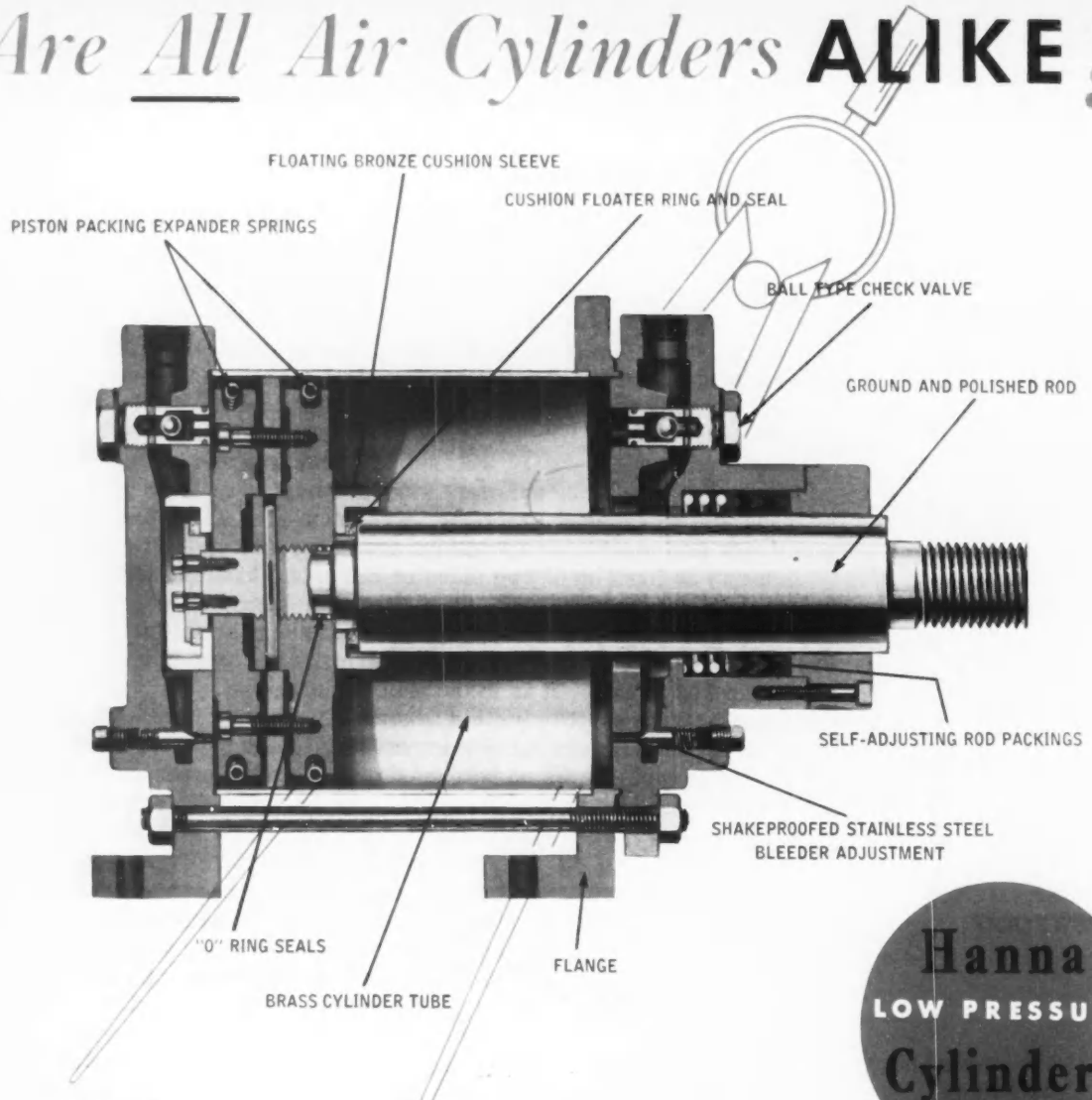
In correspondence with OTS, the British have flatly stated that they consider shell molding a war time development, and they do not recognize the rights of Croning to any royalties.

IN OPPOSITION

On the other side of the fence are Croning and Crown Casting Associates of Boston. When Croning filed a patent application in the U. S. Patent Office in 1947, he assigned rights to Crown. They claim that the process detailed in OTS's report won't work, and improvements developed by Cron-

(Continued on page 115)

Are All Air Cylinders **ALIKE?**



Hanna LOW PRESSURE Cylinders

Not when it comes to cushion sleeves, flange design or the packing of pistons and piston rods. Each of these elements of the Hanna low pressure cylinder provides special benefits for you. Notice the expander springs which insure uniform contact of piston packing with cylinder; the cork floater ring facilitating cushion alignment with head and insuring a seal during cushioning; the spring-backed chevron rod packings, self-adjusting for consistently correct compression; the flange design permitting removal of front head without disturbing mounting. These Hanna-engineered features are refinements resulting from fifty years' experience in design and application of pneumatic and hydraulic equipment. To you they mean increased efficiency—decreased maintenance.

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Hanna Engineering Works

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1763 Elston Avenue, Chicago 22, Illinois

ing since the war are the key to successful shell molding. And further, when they get the patent issued, founders using the process will have to pay royalties.

Other than that, Crown Associates won't talk. However, it is understood that Croning has sent in four patent applications to the Patent Office since 1947, but nobody knows the status of these except Crown. The big question is: Are there four applications for four different improvements or did the Patent Office refuse to issue a patent on the first three applications? The Crown organization says that they will be able to make a statement sometime in June, but other industry observers think they are just stalling and the situation will not be clarified.

There's one mysterious loose end in the dispute that might break the situation wide open. Confidential Memos reveal that Croning applied for a Swiss patent in 1938 and in 1939, and nobody now knows what happened to these applications.

SITUATION TODAY

As a result of the controversy, nobody is willing to talk for publication about shell molding and their experiences with it. Most foundries using the process have clamped down a tight blanket on discussion of the process with visitors, and are even tagging new and obscure names on their shell molding operations to disguise them. However, the plastic companies who sell the resin have been pouring out literature.

Monsanto, one of the four big suppliers, says they sold several million pounds of resin for shell molding last year; they expect to double their sales this year; and expect the plastics industry to increase sales 10 times by 1957.

Discrete inquiries indicate that over a hundred U.S. foundries are using shell molding in actual production. And over a hundred more are working in the pilot plant stage. OTS's latest report on shell molding (IR 7734) says that shell molding is being used for automotive parts that were formerly fabricated, forged or cast; railroad casting; boiler sections; aviation castings; plumbing fittings; pressure pipe; and other products. Metals that have been cast include aluminum, grey iron, nodular iron, malleable iron, low-leaded low-tin bronzes, and high alloy steels.

CHILEAN RENEGE

Chile's decision to halt copper shipments to the U.S. at the fixed price of 27 1/2 cents a pound may start hurting in July allocations. NPA plans no allocation cuts for June, but the situation is serious.

Chile was to supply the U.S. with one-third of its 1953 copper requirements and the copper supply started to show signs of easing for the first time in May. But then the mines went on strike. When mine owners were slow to settle the strike, the government stepped in, cancelled the U.S. contract, and put all Chilean copper on the open market for the highest bidder.

The U.S. plans to sweat out the ban for a time before reaching an agreement with Chile on their demand for a higher price. Officials believe Chile will have trouble selling all its metal at the price it wants. If agreement is not reached for a long time, copper supplies will be as tight as at anytime since the mobilization program started.

Even with Chilean copper, allocations were running 16,000 tons a month behind requirements.

STRIKE THREAT

The May oil strike is typical of what industry can expect for the rest of 1952. Washington authorities predict more strikes for the rest of the year than anytime since the record year of 1946. As usual, steel will set the pattern, and all the big unions will demand as much or more for their members. Washington's highly publicized bungling of the Steel case will make government intervention ineffective. Congress will attempt some kind of new legislation but strikes will make materials and component supplies hard to predict.

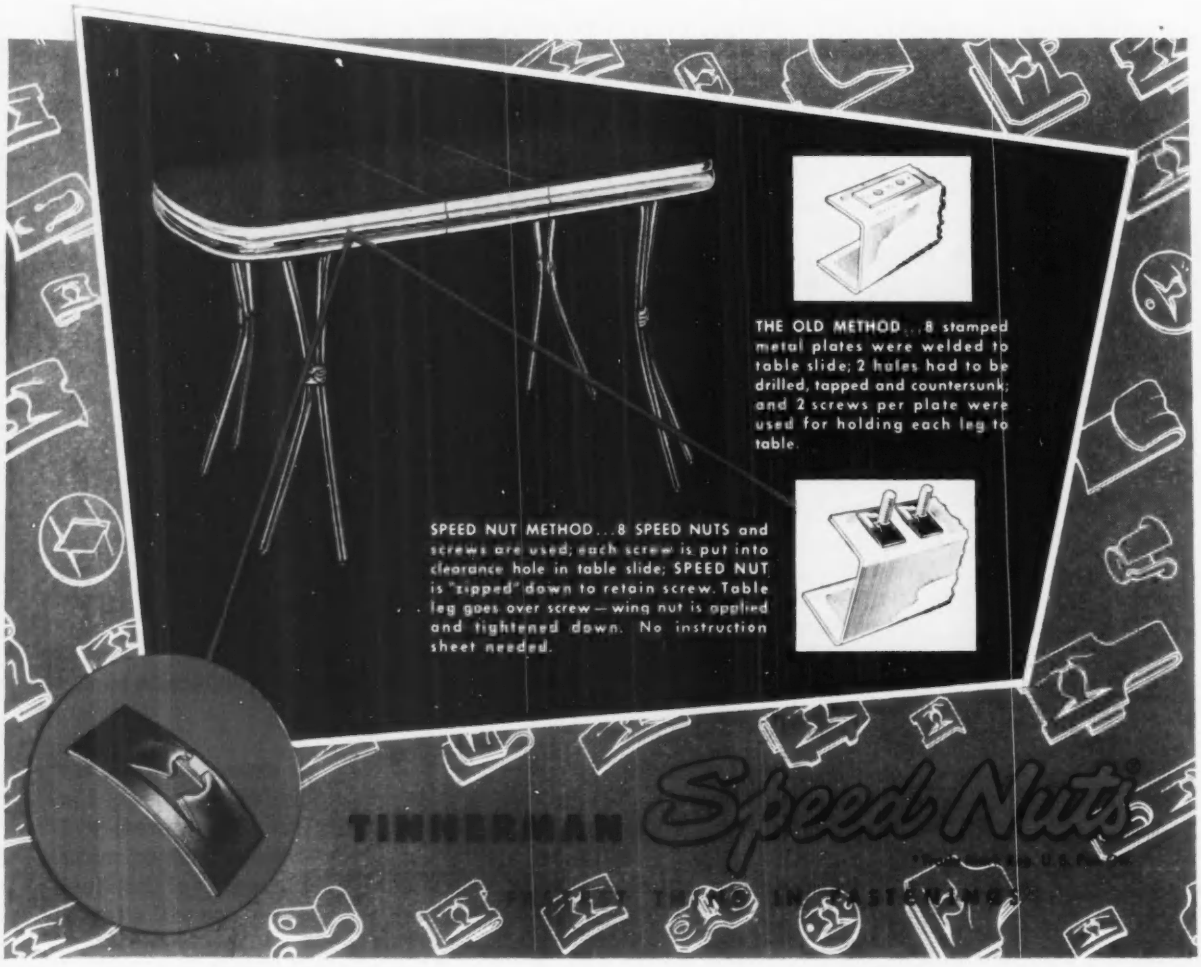
ZIP-ON SPEED NUT® *Tables 83%* ASSEMBLY SAVINGS

Merit Table Co., Inc., changes to standard Zip-On SPEED NUTS for attaching table legs—improves product quality—saves 4 assembly steps!

Coming up with an 83% assembly savings—in the face of today's rising costs—is quite an accomplishment! How did Merit Table Company, Inc., of New York, N. Y., do it? Simply by trading in a complex production cycle for the streamlined SPEED NUT principle of spring tension fastening! It once required two presses, a tapper and a spot welder to attach fasteners for table legs. Now—standard Flat-Type Zip-On SPEED NUTS are quickly applied by hand—releasing this equipment for other production.

Added to this 83% savings is the greater customer satisfaction Merit has built into their product. Since the legs are assembled to the table by the customer, it's important that the job be made simple and easy. All the fumbling and working "blind" that was necessary in positioning screws and nuts to attach the table legs has been eliminated by quick-on, stay-on SPEED NUTS!

Perhaps there's a SPEED NUT "Savings Story" waiting to be found on your production line—better fastening engineering can pay you big dividends! Call in your Tinnerman representative for technical assistance. And write for your copy of Tinnerman "SAVINGS STORIES", a FREE booklet showing savings made in a wide variety of fastening problems in industry: TINNERMAN PRODUCTS, INC., Dept. 12, Box 6688, Cleveland 1, Ohio. *In Canada:* Dominion Fasteners, Ltd., Hamilton, Ontario. *In Great Britain:* Simmonds Aerocessories, Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S.A.—7 rue Henri Barbusse, Levallois (Seine), France.


THE OLD METHOD...8 stamped metal plates were welded to table slide; 2 holes had to be drilled, tapped and countersunk; and 2 screws per plate were used for holding each leg to table.
SPEED NUT METHOD...8 SPEED NUTS and screws are used; each screw is put into clearance hole in table slide; SPEED NUT is "zipped" down to retain screw. Table leg goes over screw—wing nut is applied and tightened down. No instruction sheet needed.
TINNERMAN
Speed Nuts

We Love To Be Fooled

ONE OF THE TOP EXECUTIVES of an internationally known corporation once said, "People love to be fooled and hate the person who unfools them." This is only too true. A person who has been taken in by deception and chicanery becomes angered, or at least much annoyed, with the person who might reveal to him the true facts. He feels that he is being ridiculed. At the same time, the stories about people getting fooled are often amusing. P. T. Barnum had it all figured out and made a fortune on it.

We must recognize that fooling people is a great business. Much of the consumer goods advertising is based upon fooling the people and playing on words. In this country we are about to see a veritable torrent of political oratory, most of it designed to fool the people one way or another. If it were possible to eliminate fooling the people, all of the politicians, and most of the lawyers would either have to find new occupations or go on relief. But nobody really wants to prevent fooling people except perhaps some engineers, scientists or teachers.

Serious minded engineers cannot see any humor in men selling cattle by the pound that have been fattened on water. Of course the "watered stock" give the smart aleck salesmen more money at the expense of the purchaser. Fifty years ago such men were lauded for their smart salesmanship. Today they would be put in jail. But at any time, the serious minded scientists and engineers would frown upon it. And they would be accused of lacking a sense of humor.

Engineers must recognize that the high pressure sales type of personality will always be with us. They must also recognize that there will always be those who will fool the people and profit thereby. Regardless of all laws and conventions, it will be impossible to prevent exaggeration and misinformation being presented in sales appeals. It is just a part of life. So one might just as well be amused rather than aggravated.

However there is one consolation that the engineer has. Although salesmanship is still highly important, relatively it is being overshadowed by engineering. Today it is essential for a manufacturing industry to offer quality products at a competitive price. This can be done only through sound engineering of both design and production. That is why most of our industries are now being directed by scientists and engineers. Whereas in the previous century, smart salesmanship that was adept at fooling the prospects was the essential ingredient to business success, today many or most of the major industrial problems that must be solved can be handled only by engineers.

The engineering mind will probably never be able to fully understand the sales mind. Engineers will probably always be criticized for being too serious and factual. In general salesmen will always find it difficult to understand engineers. But as the world steadily advances into the higher realms of science and engineering the position of the engineer in the industrial picture becomes more and more important. Although people love to be fooled it is only realities that build higher standards of living and greater national security.

G. F. Zodenholt

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NEW DEPARTURE

BALL BEARINGS

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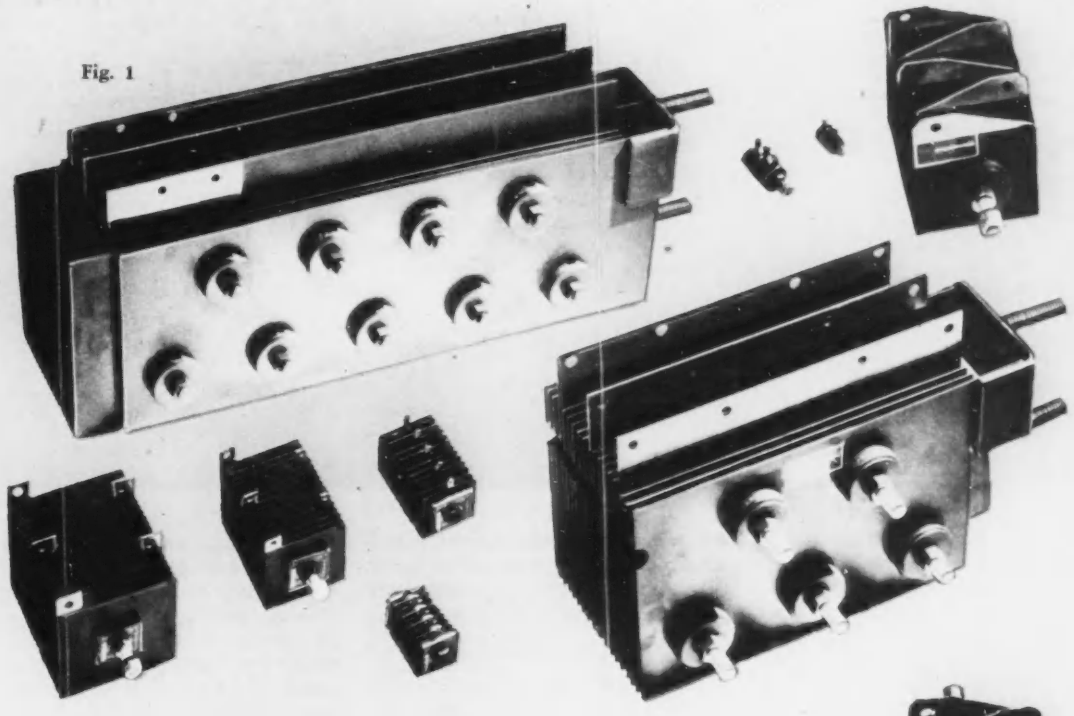
Fig. 1



Higher Current Metallic Rectifiers

New designs for magnesium-copper sulfide rectifiers have boosted the current limits for this type of unit to 200,000 amperes. And even at such currents, regulation is good and overall size comparatively small.

MILTON E. GAMBLE*
Chief Engineer, Rectifier Div.,
P. R. Mallory & Co., Inc.

THE DEVELOPMENT of high current rectifier stacks is a result of a demand for satisfactory units for resistance welding machines. This application required intermittent output currents from 20,000 to 100,000 amp at two to three volts. These ratings—and higher—are now available from magnesium-copper sulfide rectifiers.

Study of the voltage and current characteristics of the various types of metallic rectifiers discloses the reasons for the selection of these rectifiers for the resistance welding application. Normal voltage and current ratings of selenium, copper oxide, and magnesium-copper sulfide rectifiers, based on a three-phase bridge rectifier with one cell in series and one cell in parallel in each leg, are given in Table I. Voltages and currents required for resistance welding also are shown.

The permissible current density for the magnesium-copper sulfide rectifier is many times the maximum allowable current rating for other types. While the latter can be used, theoretically, for high current applications, considerably larger plate areas are necessary to keep current densities below the recommended maximums. At greater densities, the plates overheat. The large plate areas needed make the size of such rectifiers prohibitive. The bulky units would be difficult to mount on transformers and machines.

As is noted from the column of a-c voltage ratings, the back voltage of a magnesium-copper sulfide plate is considerably less than the ratings for other types. It is this factor that has lead to the widespread use of selenium

* *Mr. Gamble is now an electrical engineer for R. O. Whitesell & Associates in Indianapolis.*

Table I—Characteristics of Plate Rectifiers

Rectifier	A-c volts	D-c volts (6–1–1 rectifier)	Current density (6–1–1 stack, forced draft cooling)
Selenium	18	21.5	1.25 amp/sq in.
Copper oxide	6.8	6	0.6
Magnesium-copper sulfide	3.5	2.9	50
Resistance welding requirements	.....	2.5–3.5	20,000–80,000

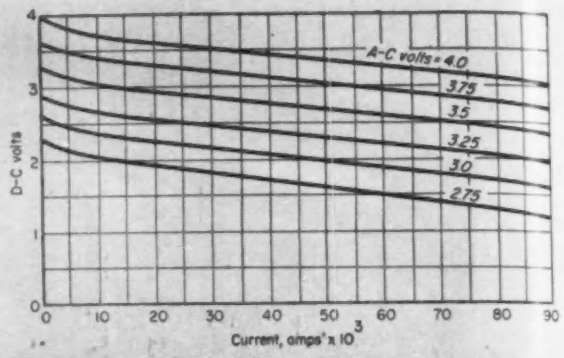


Fig. 2—Regulation curves for large high current magnesium-copper sulfide rectifiers. Average regulation is about 30 percent, remarkable in view of the tremendous currents drawn.

rectifiers in applications requiring higher voltages. However, the 3.5 v per plate rating for the magnesium-copper sulfide rectifier is sufficient for most high current power packs.

In the resistance welding application, the magnesium-copper sulfide rectifier is used at input potentials to 4.0 volts, which is slightly higher than normal. At the lowest duty cycles, the plates are operated at current densities about 8 times the recommended continuous duty ratings.

The regulation curves of Fig. 2 are typical of those obtained with magnesium-copper sulfide resistance welding rectifiers. These curves represent the basic electrical design information for rectifier type welding machines. Transformers usually provide an open circuit secondary potential of 4.0 volts and a full load potential of about 3.5 v at a duty cycle of about one to three percent. Under these conditions, the rectifier provides an output of approximately 2.5 d-c volts at the maximum output current. With proper machine design, this voltage is entirely adequate.

At a continuous input of 3.5 v, Fig. 2 indicates a no-load output of 3.2 v and a full load output of 2.45 volts. This corresponds to a regulation of 30 percent, meaning that voltage drops by this amount as the current value goes from no load to a maximum. Since the full load output current is at least 8 times the normal continuous duty rating of the rectifier, this regulation is outstanding.

The excellent regulation characteristic of the rectifier is brought about by the inherent decrease in the impedance of the material with increase in load current. The relationship between rectifier impedance takes the form of the curve of Fig. 3. The voltage drop, which is equal to current times impedance, does not increase directly with current. The decrease in impedance partially offsets the current rise.

Stack Arrangement

Although the operation of metallic rectifiers at the extremely high currents involved in resistance welding is new, the magnesium-copper sulfide rectifier has given satisfactory service in various applications for over 20 years. In Fig. 1 is shown rectifier stacks of conventional design.

The rectifier stacks in Fig. 1 incorporate cells of several sizes, ranging from about $\frac{5}{8}$ in. to slightly more than two inches in diameter. The largest cell is the same size as the cell used in resistance welding applications, but is processed to work at a slightly lower input voltage.

Conventional rectifier stacks, except those with the lowest current ratings, include radiator plates to facilitate cooling. These plates, which may have several times the area of the cell, are made of steel, aluminum, or magnesium. In a majority of stacks, washers of steel, aluminum, or magnesium are assembled adjacent to the rectifier cells to increase the spacing between radiator plates. This spacing is an important factor in determining the ability of a stack to operate within the prescribed temperature limits.

Magnesium-copper sulfide rectifier stacks operate normally at temperatures of 125 to 130 C, measured at the periphery of the rectifier cell. For loads to approximately 10 amp the convectional movement of air across the radiator plates provides adequate cooling. For greater currents, forced draft cooling must, as a rule, be used.

The current rating of a particular rectifier stack depends on the area of the cell; the area of the radiator plate; the method of cooling (convection or forced draft); the spacing between radiator plates; the number of cells in parallel in each element of the stack; the duty cycle; and, to some extent, the type of load. For single phase, full wave rectifier stacks with one cell in parallel in each element of the stack, the continuous current rating varies from about one ampere for the smallest cell, convection cooled, to 100 amp for the largest cell when cooled by the forced circulation of air.

The voltage ratings, both a-c and d-c, of the rectifier stack depend primarily on the number of cells in series in each element of the stack. The ratio of d-c output volts to a-c input volts is a function of the type of load for single phase rectification. This ratio is about 0.45 for inductive loads; 0.50 for resistive loads; and 0.75 for capacitive loads. In three phase applications the voltage ratio is independent of the type of load. For three phase full-wave rectification the value of this ratio is 0.8, approximately.

Because the magnesium-copper sulfide rectifier is basically a low voltage, high current device, it is customary for rectifier stacks to have several cells in series in each element of the stack. Practically, however, it is inadvisable to include too many cells in series in each element.

Magnesium-copper sulfide rectifier cells, as well as cells of other types of metallic rectifiers, vary somewhat from one to another in reverse resistance. Because of this variation in resistance, the reverse or blocking voltage does not divide perfectly uniformly over cells arranged in series. This presents no problem as long as the number of cells in series is limited to 7 or 8. But with greater numbers, the voltage

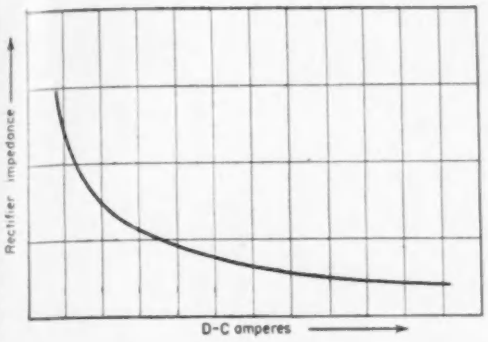


Fig. 3—**Relationship between rectifier impedance and output current. The forward impedance of the plates is small, being measured in micro-ohms.**

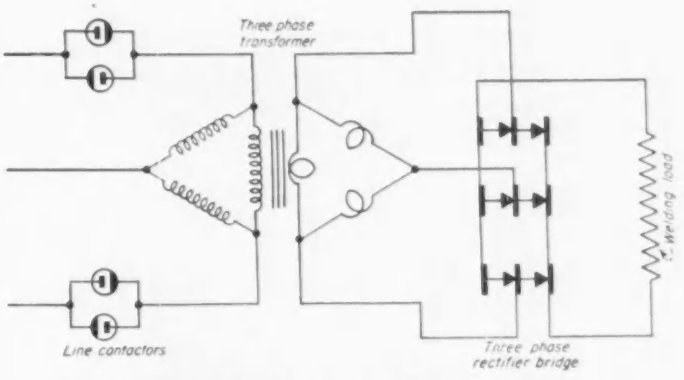


Fig. 4—**Schematic diagram of power supply circuit for resistance welder. Three phase a-c input is converted to direct current by rectifier bridge. Contactors are in two of the supply mains.**

inequality may be such that excessive voltage is applied to one cell even though the average volts per cell is well within the prescribed value.

As a result, for d-c output voltages above 12-15, it is desirable to operate separate stacks from separate secondary windings, with the various output circuits connected in series.

To obtain output currents greater than those available from single cells, it is common practice to group cells in parallel as well as in series in rectifier stacks for many applications. Thus, the largest rectifier shown in Fig. 1 is a 6-3-9 stack. This is standard rectifier terminology, indicating that the stack includes three cells in series and nine in parallel in each of the six elements, or legs, of the three phase full wave bridge. This particular stack will deliver 750-d-c amp, continuously, at 6 volts.

Rectifier stacks of the types illustrated in Fig. 1 have found extensive application in the fields of electroplating, aircraft engine starting, and battery charging. These rectifiers have also been used widely in rectified a-c ignition systems for automobiles, and in laboratory power supplies, electric fence power supplies, magnetic chucks and electromagnets. In such uses, moderate to high currents at relatively low d-c voltages are required. But only in the field of resistance welding is full advantage taken of the high permissible current density and unusual regulation characteristics of the magnesium-copper sulfide rectifier.

Welder Operation

As noted from Fig. 4, the circuitry involved in the resistance welding application is straightforward and conventional. The essential elements are the three-phase transformer, the three-phase full-wave rectifier, and the work, which constitutes a resistive load on the rectifier. Magnetic or ignitron contactors in the input lines to the primary windings of the transformer complete the circuit. Standard electronic control apparatus actuates the contactors.

One important function of the rectifier is to provide interconnection between the three-phase supply and the work, which is inherently single in character. Another function is the obvious one of providing direct current to the welding circuit. The use of direct current practically eliminates the inductive reactance normally associated with alternating currents of large magnitudes in the arms of the welding machine.

In the construction of rectifier type welding machines, it is customary to connect the rectifier directly to the transformer, mechanically as well as electrically. An actual rectifier-transformer assembly, capable of providing intermittent welding currents up to 40,000 amperes, is shown in Fig. 5. The rectifier stack measures 20¾ by 8 by 6 in. and weighs about 75 pounds. The three-phase transformer is no larger than those normally used in single-phase a-c machines of equivalent capacity. The rectifier bolts directly to extensions on the secondary castings of the transformer.

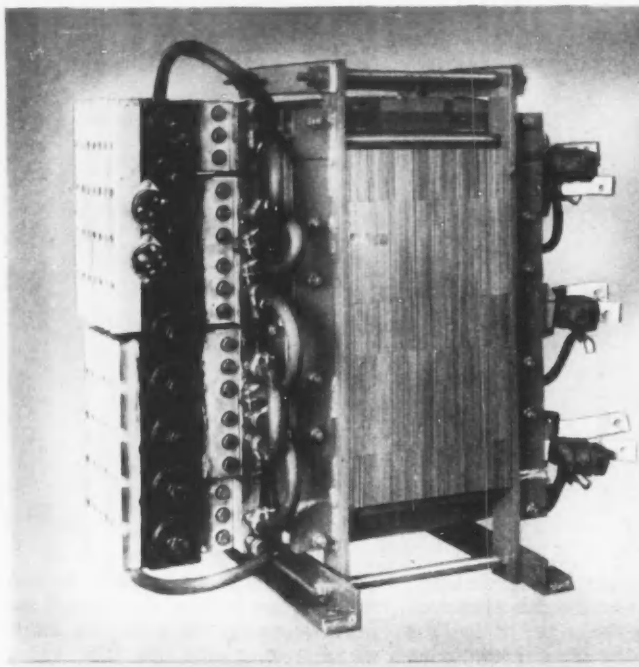
The rectifier consists of 216 magnesium-copper sulfide cells arranged in 24 layers between 25 nickel plated copper plates. Rectifier cells are slightly more than two inches in diameter. Separate washers, or elements, of magnesium and copper sulfide are bonded to the cells in an electroforming operation. The copper plates are one-eighth inch thick and serve as a-c and d-c terminals. The a-c terminals are brought out straight, while the d-c terminals are bent at right angles to form flanges for bolting to the arms of the welding machine. The upper and lower a-c tabs are projections from the same terminal plates. This construction permits the closing of the transformer delta through the rectifier plates, thus avoiding the need for external delta closing members.

A photograph of a rectifier type resistance welding machine is given as Fig. 6. This machine is an RWMA size 3, direct-air operated, press type, spot welder. It is capable of welding to Army-Navy specifications two pieces of 0.125 in. 24ST aluminum; two pieces of 0.140 in. 18-8 stainless steel; or two pieces of 0.219 in. low carbon steel. The apparatus is no larger than a-c machines of equivalent capacity. (Standard frames customarily are used for rectifier type welders). The cabinet on the side of the machine houses conventional electronic apparatus for controlling the timing of the welding operations.

This particular welding machine utilizes three rectifiers of the type shown in Fig. 7, with the output circuits connected in parallel. Each stack contains 12 layers of 12 cells each, arranged between one-quarter inch copper terminal plates. Electrically, each stack is a 6-1-24 rectifier, capable of providing, at the lower duty cycles, currents up to 26,000 amperes.

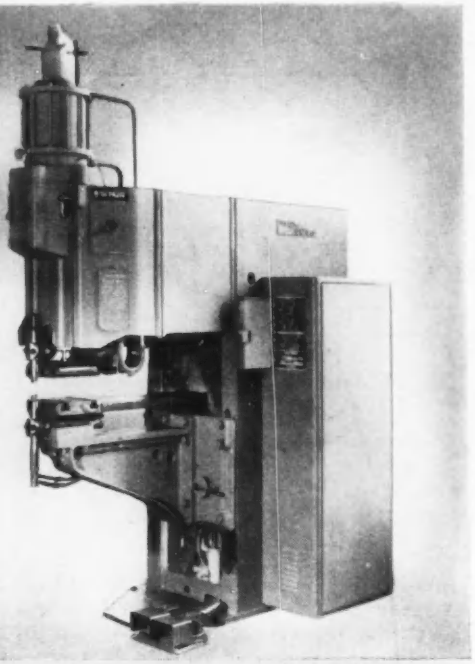
Another form of the resistance welding rectifier is illustrated in Fig. 8. This rectifier is a 6-1-18 stack, including 6 elements, each of which has one cell in series and 18 cells in parallel. At a three percent duty cycle, the rating of the rectifier is 20,000 amperes.

Plate projections shown in Fig. 8 are a-c terminal tabs, which assemble



Acme Electric Welder Co.

Fig. 5—In this power pack for resistance welder, the rectified unit (left) is mounted directly on the transformer. Rectifier core is water cooled. Such cooling multiplies capacity many times.



Taylor-Winfield Corp.

Fig. 6—Resistance welding machine uses plate rectifiers to convert alternating to direct current. Operation is controlled by electronic apparatus at right.

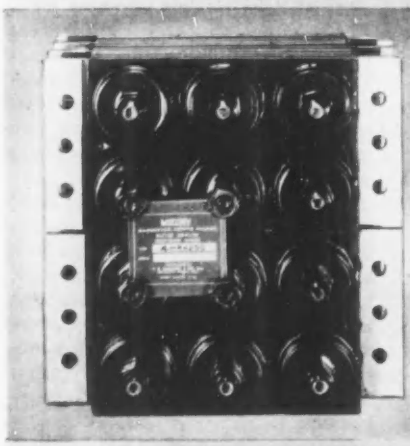


Fig. 7—This is one of three rectifier stacks used in the welder. Outputs are connected in parallel, to provide more than 60,000 amperes.

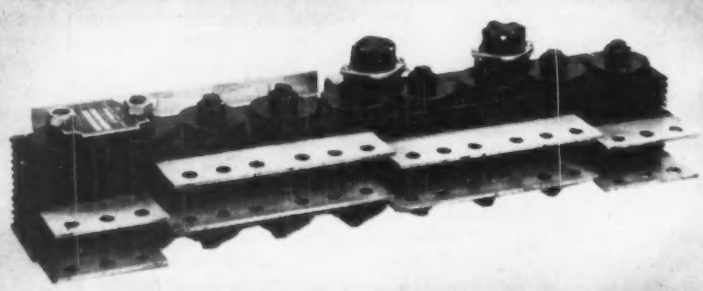


Fig. 8—Another form of the magnesium-copper sulfide rectifier. Note thermostatic switches at top right of the stack. These act as coolant control and temperature protection. When temperature drops, coolant must be shut off to prevent condensation of moisture on the rectifier plates.

directly to the cast copper secondaries of the welding transformer.. The size of the stack is comparatively compact, as can be judged from the picture. Weight is about 40 pounds.

The d-c termination takes the form of right-angle flanges, which can be seen over the top of the stack in Fig. 8. Copper castings, which provide connection to the output circuit of the welding machine, bolt to these flanges by means of drilled and tapped back-up bars. D-c castings, as well as transformer secondary castings, are water cooled. This is a convenient and effective means for the removal of heat from the rectifier. Where additional cooling is required, as in continuous duty applications, copper tubing is soldered to the edges of the terminal plates.

Thermostatic switches protect the rectifier from excessively high and low temperatures, Fig. 7. A normally open switch turns off the coolant if the stack temperature falls below a specified value, thus preventing the condensation of moisture on the rectifier.

Where higher output voltages, or even higher currents are required, it is practical to operate several rectifiers in series, in parallel or in series-parallel combinations.

Removable Keyless Couplings For Motor-Generator Sets

G. E. JAMIESON
Design Engineer, Large Motor & Generator Department, General Electric Company

Design of a keyless flange coupling that is shrunk on shaft with an interference fit and is removed by expanding hub bore with hydraulic pressure. Keyless coupling reduces machining costs and makes possible a shorter overall length of connected equipment.

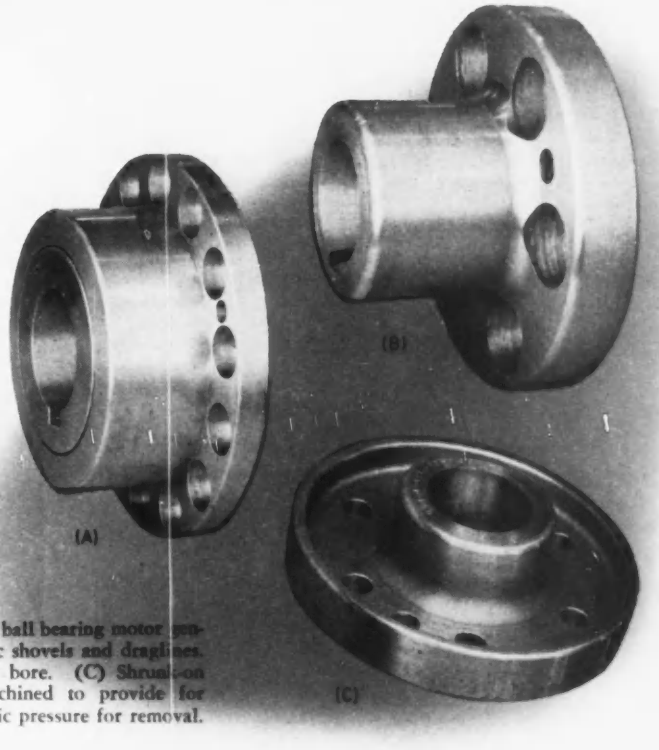


Fig. 1—Types of couplings used with ball bearing motor generator sets for powering large electric shovels and draglines. (A) Flexible gear type. (B) Taper bore. (C) Shrunk-on flange coupling where shaft is machined to provide for expanding the hub bore with hydraulic pressure for removal.

IN INDUSTRIAL APPLICATIONS such as ball bearing motor generator sets for powering large electric shovels and draglines used in open pit strip mining, where down time carries a premium price tag, it is essential that maintenance time for replacement of parts having a finite life be held to the absolute minimum.

For many years such rotating machines have been built with either flexible gear type couplings having a light fit on the shaft extension or taper bore solid couplings on tapered shaft extensions. For this application, both types of couplings have numerous disadvantages of which the most outstanding are:

FLEXIBLE COUPLINGS. (1) Require a key and keyway that introduce stress concentrations in the shaft extension; (2) The maximum misalignment for which the couplings are designed often results in undesirable vibration leading to reduced bearing life. Hence, in practice they must be as carefully aligned as a solid coupling; (3) Require lubrication and maintenance; and (4) Necessitate two bearing construction on all machines, thus adding to bearing maintenance and the overall length of equipment.

TAPER BORE COUPLINGS. (1) Usually require selective assembly with the fit hand lapped; (2) Must be finish machined on face and rabbet fit after mounting on shaft, and usually require remachining after removal and reassembly; (3) Require longer hub than straight bore couplings as shown in Fig. 1; and (4) Require a key and keyway that introduce stress concentrations in the shaft extension.

In view of these undesirable features, a design project was undertaken to develop a coupling in which none of the disadvantages of the taper bore and flexible couplings was present. The project resulted in the development of a coupling with a straight bore having no keyway. The coupling is shrunk onto the shaft extension with an interference fit and is hydraulically removable.

In the basic design of these couplings, the length and the outside diameter of the hub are $1\frac{1}{2}$ times the nominal bore. The rabbet fit and the outside diameter of the flange are matched to previously established solid coupling sizes. The allowance for interference fit is 0.001 in. per inch of nominal bore diameter. Coupling material is 0.20 carbon steel.

Having established these basic proportions, stresses were calculated from the following theoretically derived

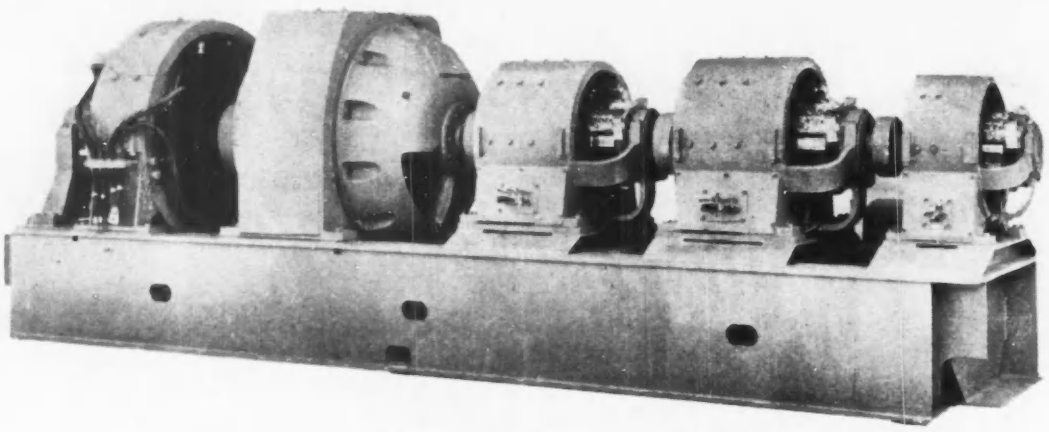


Fig. 2—A motor-generator set for a dragline excavator. Four keyless couplings are used to connect in tandem a synchronous type hoist and drag generator, two swing generators, and a thermo-magnetic shunt exciter.

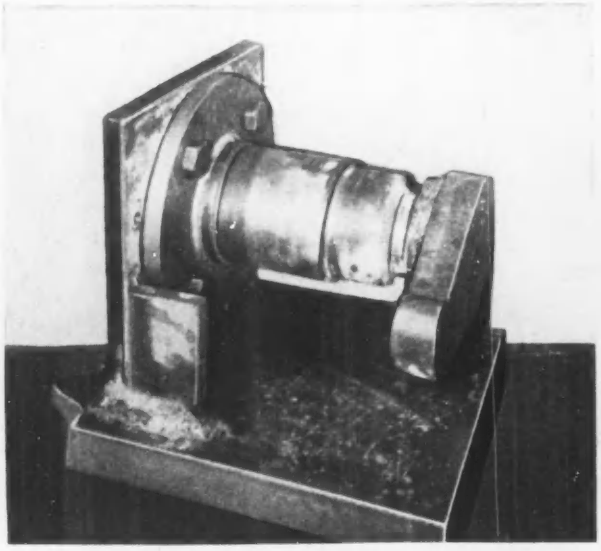


Fig. 3—Fixture and dummy assembly for measuring slippage torque of interference fits ready for mounting in a testing machine. Tests confirmed previously established design criteria.

Fig. 4—Closeup of shaft extension showing annular groove and connecting oil holes for admission of hydraulic pressure to coupling bore.

formulas; where

S_R = radial stress at the coupling bore, psi
S_T = tangential stress at the coupling bore, psi
E = modulus of elasticity, material in shaft and coupling assumed to be identical, 30×10^6
A = nominal fit diameter, in.
B = outside diameter of hub, in.
C = allowance in diameter for interference fit, in.
L = length of fit, in.
T = design torque required to slip coupling on shaft, lb in.
μ = coefficient of friction between coupling and shaft, assumed to be 0.2
S_S = shear stress in outside fibers of shaft at torque T, psi

$$S_R = (EC/2A)\,[1 - (A/B)^2] \quad (1)$$
$$S_T = (EC/2A)\,[1 + (A/B)^2] \quad (2)$$
$$T = \mu\,(\pi AL)(S_R)(A/2) = \pi\mu\,A^2LS_R/2 \quad (3)$$

From the established proportions

$$B = 1.5A,\ C = 0.001\ A,\ \text{and}\ L = 1.5A$$

substituting these values and the value of E and μ in Eqs (1), (2), and (3) yields

$$S_R = 8{,}340 \text{ psi};\ S_T = 21{,}660 \text{ psi};$$
$$\text{and } T = 1{,}251\,\pi\,A^3 \text{ lb in.} \quad (4)$$
$$\text{and } S_S = 16T/\pi\,A^3 = 20{,}016 \text{ psi}$$

Since this value of S_S is well within the yield strength of the shaft material, the couplings will slip on the shaft before the shaft can be injured by a torque load. The torque transmitting ability of the assembly when compared with the rated torque requirements of the machines in service yields at least a safety factor of 10 for any given size.

In view of the high degree of reliability required in open pit mining operations and the assumptions made in deriving the design formulas, it was deemed essential to check the slippage torque of the couplings by laboratory tests. A dummy assembly of shaft and coupling was made up and mounted on a fixture as shown in

Fig. 3, suitable for use in a mechanical testing machine. It was assumed that the design Eqs (1), (2) and (3) were valid and the assembly was tested to determine the coefficient of friction. On repeated tests of the same assembly, plus additional tests on assemblies where one or the other parts was changed, the coefficient of friction was found to be 0.2 plus or minus 5 percent. These tests confirmed the previously established design criteria for this type of keyless coupling.

With an interference fit of 0.001 in. per inch of bore diameter, where the thermal linear coefficient of steel is 6×10^{-6} in. per in. per deg F, the temperature rise required to expand the bore diameter 0.001 in. per inch of bore is

$$0.001A/6 \times 10^{-6} \times A = 166 \text{ deg F}$$

the coupling, therefore, if heated uniformly to a temperature of 400 F can be readily slipped in place over the shaft. To achieve uniform temperature throughout the coupling, heating should be done in a controlled oven or in an oil bath. Heating with any kind of a torch is not recommended.

The feature that makes the coupling hydraulically removable is in the shaft extension rather than the coupling itself. On the shaft extension is machined an annular groove, spaced in from the end of the shaft by a short sealing land, Fig. 4. This groove is connected by two intersecting drilled holes in the shaft to a pipe thread connection in the end of the shaft.

To remove the coupling, oil is pumped into the annular groove, Fig. 5. At an oil pressure of about 25,000 psi, the hub section immediately over the groove expands enough for the oil to start creeping into the fit in both directions from the groove. The oil then progresses slowly along the length of the fit. The end effect of the corner at the face end of the hub maintains the hydraulic pressure until the entire length of the bore has expanded and oil appears at the back end of the hub.

After oil appears at both ends of the hub, the coupling can be pulled with a simple coupling puller and a 10 or 12 in. wrench, until the oil groove is uncovered. The final pull over the outer land is not much more difficult, since the area of the land is quite small. The volume of oil flow is so small that only a small hand pump is required. This pump and all connections usually are purchased as part of original equipment.

Couplings of this type have been disassembled many times from the same shaft with no evidence of distortion or dimensional change in either the shaft or coupling. Couplings have been assembled consecutively on several different shaft extensions with negligible face and rabbet fit runouts proving the feasibility of random assembly. This design with its cylindrical bore lends itself to lower cost tooling and better quality control than the taper bore type, and makes possible a shorter overall length of the assembled units as shown in Fig. 6. The inherent weaknesses of keys and keyways, particularly as stress raisers, are not present in the keyless coupling. The design also does not require heavy press equipment to remove the couplings.

These keyless hydraulically removable couplings are designed in five nominal bore sizes ranging from $2\frac{1}{4}$ to $3\frac{3}{4}$ in. in steps of $\frac{3}{8}$ in. Each nominal size can be bored to plus or minus $\frac{1}{8}$ in. from the nominal size; so that the entire range from $2\frac{1}{4}$ to $3\frac{3}{4}$ in. is covered in $\frac{1}{8}$ in. steps.

Since the nature of large excavating equipment in open pit mines precludes the ready availability of heavy shop equipment and limits the space available for maintenance work, this application has been selected as the primary field for this type of coupling. On some motor generator sets for shovels, the overall length for given ratings has been reduced as much as 10 or 12 in. This reduction in length is probably sufficient justification for the use of these keyless hydraulically removable couplings. Where better shop facilities are available and space is not critically limited, of course, the common types of couplings will continue to serve their purpose well.

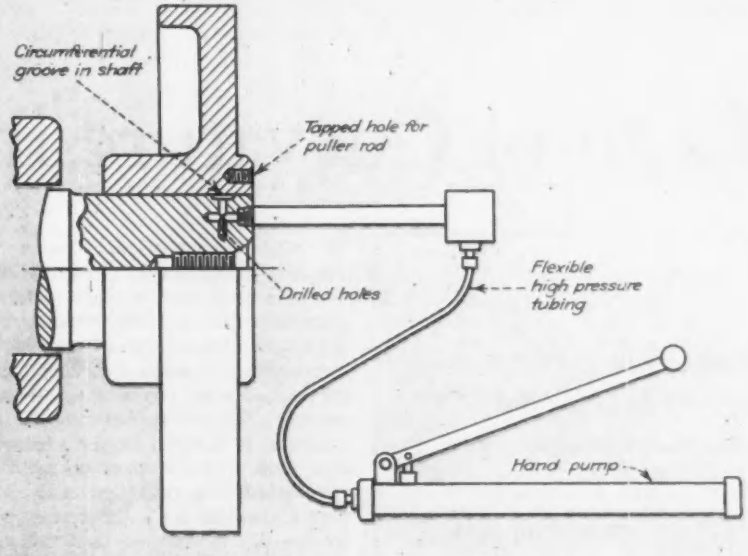


Fig. 5 — Hand pump and piping connections for building up an oil film in the interference fit.

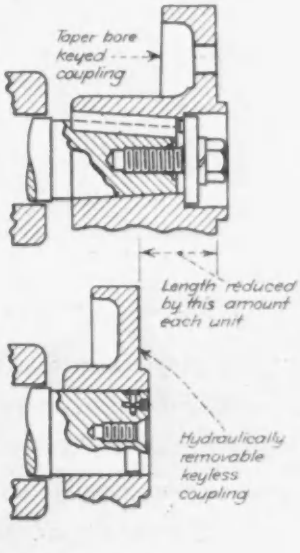


Fig. 6 — Length of shaft extensions required for taper bore coupling and for keyless coupling.

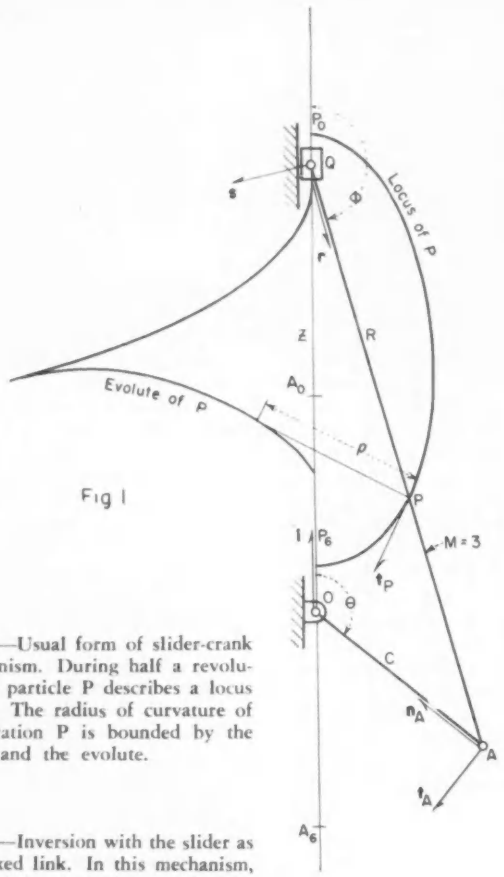


Fig. 1—Usual form of slider-crank mechanism. During half a revolution a particle P describes a locus P_0PP_6. The radius of curvature of any station P is bounded by the locus and the evolute.

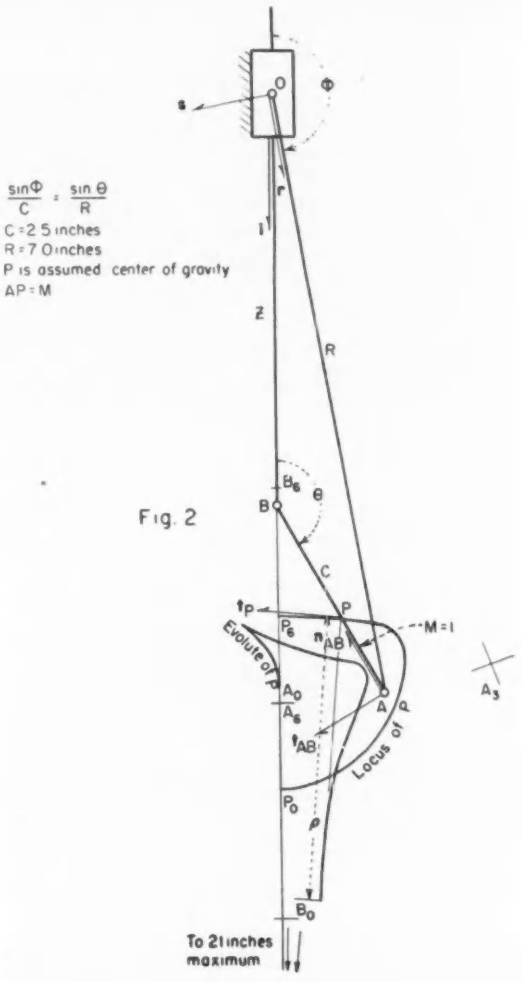


Fig. 2—Inversion with the slider as the fixed link. In this mechanism, crank C has both linear and angular motions. The rod Z reciprocates.

Radii of Curvature in

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Semi-graphical method for determining the radii of curvature of the locus traced by any particle in any link of a slider-crank mechanism, including the inversions. Charts of angular magnitudes for slider-crank mechanisms of several ratios are included to facilitate application of the method. Detailed steps in applying semi-graphical method are demonstrated in solution of fixed-slider mechanism.

NO CONSTRUCTION nor device is properly recognized as a machine unless at least one of its parts can and does move relative to the others during a cycle of normal operation.

Constrained motion is the one defining characteristic common to all machines. The analysis of motions in machines is founded on the principle that each movable part or link is constrained. The links generally are presupposed to be rigid bodies, although this assumption does not entirely rule out flexible and fluid bodies.

Constraint means that the displacement of one link, or of a particle in it, relative to another link, or to another

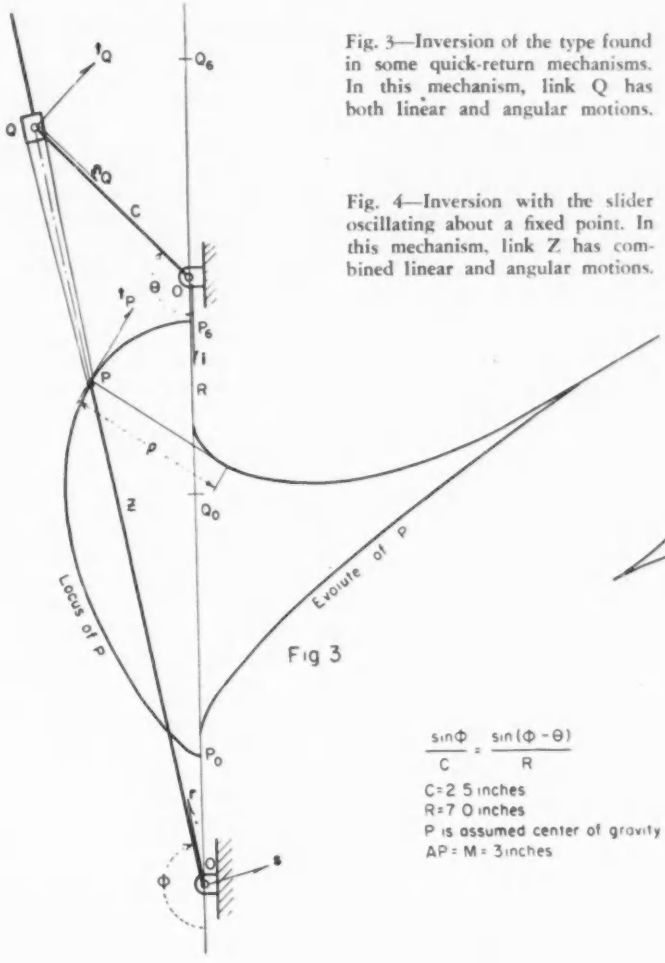


Fig. 3—Inversion of the type found in some quick-return mechanisms. In this mechanism, link Q has both linear and angular motions.

Fig. 4—Inversion with the slider oscillating about a fixed point. In this mechanism, link Z has combined linear and angular motions.

Fig 3

$$\frac{\sin\Phi}{C} = \frac{\sin(\Phi - \theta)}{R}$$

C=2 5 inches
R=7 0 inches
P is assumed center of gravity
AP = M = 3inches

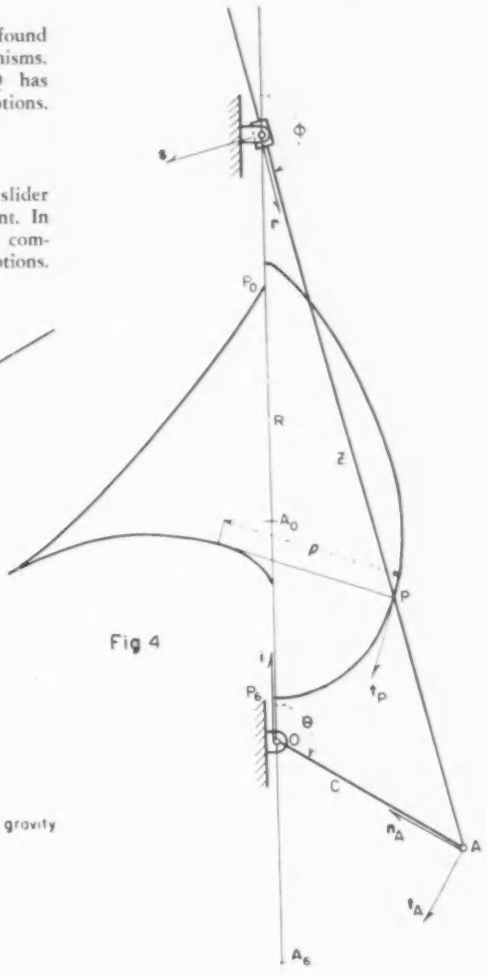


Fig 4

Slider-Crank Mechanisms

particle, always takes place in precisely the same manner regardless of how often or how fast the relative movements are repeated. Constraints cause any particle in a link to trace the same locus over and over again independently of the speed with which the path is traveled.

In the constrained motion of a part in a machine, the locus of the center of gravity is strictly a geometrical property, completely dependent upon the way in which the displacements of the body are guided by the constraints.

In the motion of a free body, the trajectories or loci traced by it are functions of the mass and speed of the body and the external forces acting on it. The path traced by the center of gravity may be thought of as a defining property of the motion.

Dynamically, whether the body is free or constrained, at any instant the kinetic energy of a moving body is the kinetic energy of translation of the whole mass of the body concentrated at the center of gravity and moving along the curve traced by the center of gravity, plus the kinetic energy of rotation of the body about the center of gravity.

The significant distinction between a free body and a constrained body is that the locus of the center of gravity of the constrained body is defined independently of the energy possessed by the body, whereas that of the free body may not be. This important difference can be used to advantage in solving problems in dynamics of machinery.

In brief, the solution of such a problem includes the establishment of the locus of the center of gravity, the determination of the velocity and acceleration of the center of gravity along the locus, and finding the angular velocity and angular acceleration of the link about the center of gravity. From these data and the mass, the inertia forces of the body can be found and

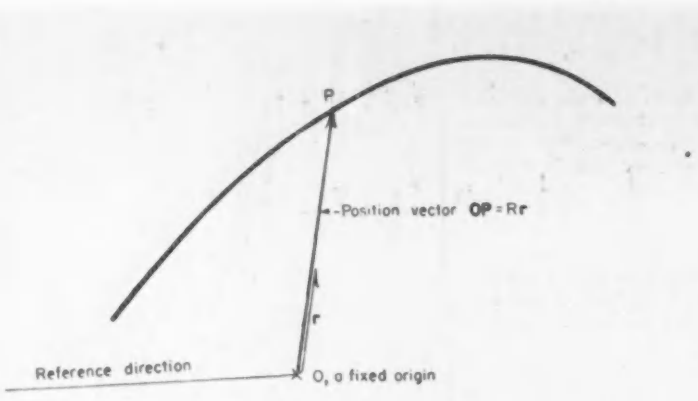


Fig. 5—Vector OP defines the positions of the points along a plane curve in much the same manner as a radius and an angle do in polar coordinates. In linkage analysis, the line of centers can be taken as the initial line from which angles are measured, just as a reference line is chosen for a system of polar coordinates.

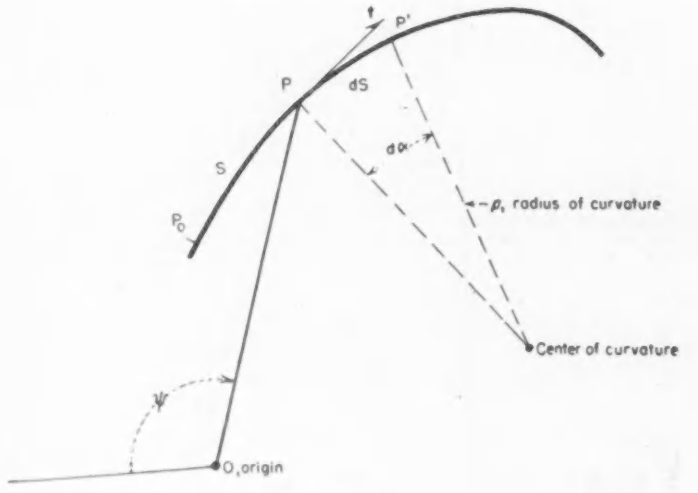


Fig. 6—The second derivative of a position vector yields a vector sum containing the radius of curvature of the path. Loci of plane motions are readily expressed by means of position vectors. Once an equation of position is established, differentiations and computations of radii of curvature proceed in the usual manner.

then transferred to the body-constraining points of the link as reactions.

Since normal components of accelerations vary inversely as the radii of curvature of the curve along which motion occurs, radii of curvature are often wanted in design calculations. They are not always easy to establish. So far as the author knows, no one has attempted to set forth a general method for finding the radii of curvature for particles constrained to move as they must in machine parts. Accordingly, the application to the slider crank mechanism described here may be new.

The mathematics upon which the method is based has been known for decades and can be verified in most any textbook of the calculus, vectorial mechanics, vector analysis, or differential geometry by anyone who desires to investigate the subject further.

In a machine, the curve along which a mass or a particle moves has a good chance of being a circle because rotation is the primary motion of machines. Many machine parts, however, have linear and angular motions simultaneously; for example, a connecting rod in a slider-crank mechanism or a connecting rod in a four-bar mechanism.

The slider-crank mechanism is chosen for discussion here because its links offer a variety of linear, angular and combined motions all within a single mechanism. This basic mechanism along with the three inversions of the usual form are shown in Figs. 1 to 4. Besides the fixed link, the mechanisms in Figs. 1 and 2 each have one link with rectilinear motion, one with angular motion and one with combined linear and angular motions. The inversions in Figs. 3 and 4 each have two links with angular motions and one with combined linear and angular motions. Thus only one link in any one of these four allied or related mechanisms has combined linear and angular motions.

When a machine part has angular motion alone, the loci traced by particles in the part are circles or arcs of circles. Radii of curvature are merely the radii of circles. They are constants.

When a machine part has only straight line motion, the loci traced by particles in the part have infinite radii of curvature; the normal components of linear acceleration have zero magnitude; and general formulas of motion reduce to special cases.

The connecting rod *R* in Fig. 1, the crank *C* in Fig. 2, the slider *Q* in Fig. 3, and the rod *Z* in Fig. 4 each has both linear and angular motions. Note that link *R* in Fig. 1 and Link *C* in Fig. 2 each has one body-constraining point that reciprocates while the other body-constraining point moves on the arc of a circle. The radii of curvature of both these body-constraining points are known; hence there remains only the problem of finding the radii of curvature of any other point in each of these links to gain a complete knowledge of the radii of curvature of any particle anywhere in these two mechanisms.

The path traced by the center of gravity *P* of a link like *R*, Fig. 1, does not usually coincide with the path traced by a body-constraining point of the link. Since the path described by the center of gravity is useful in kinetics of machinery, the present analysis is directed toward defining the path described by a point *P*, typical of the center of gravity of the link. The analysis, however, is valid for any other particle.

Kinematically this path is independent of mass. It depends solely upon the loci described by the link-constraining points; not upon the speed with

which the link-constraining points trace those loci. The independence of the direction of motion and the speed of motion is often overlooked in the analyses of displacements and velocities in mechanisms. In machines, direction and speed are always two independent quantities.

Vector methods permit the path traced by the center of gravity to be expressed by one simple equation. It will be remembered that one vector is the equivalent of two scalars in a plane. With respect to O as origin, Fig. 5, the position of any point P on the path is completely specified by a vector of length OP and having the direction from O to P. Vectors used in this way are known as position vectors.

The position vector, which inherently has both a magnitude and a direction, obviously, is the equivalent of a radius and an angle in a system of polar coordinates. Thus the position vector **OP** in Fig. 5 is equivalent to the scalar quantity having a magnitude of R units of distance multiplied by a unit vector **r**. By definition, a unit vector always has a magnitude of one; hence the unit vector is ideally suited to defining the direction of a vector with respect to some reference direction.

In linkage analysis of machines, the line of centers can be taken as the initial line from which angles are measured, just as the initial or reference line might be chosen for a system of polar coordinates.

Radii of curvature are readily computed by standard formulas from the calculus when the paths or curves are defined by equations. The usual formulas apply to equations stated in rectangular coordinates, in polar coordinates or in parametric form. The procedure in deriving curvature formulas embodies two differentiations. The application of them embodies the selection of the coordinates of the place along the curve at which the radius of curvature is wanted, and the substitution of numerical values into the suitable curvature formula.

But when an equation of the curve is unknown, getting an equation that defines the path becomes a perplexing problem. Setting up an equation in rectangular coordinates is frequently insurmountable. An equation in parametric form is generally less difficult to establish. In contrast, the loci of plane motions are particularly easy to visualize and express by means of position vectors. Once an equation of position has been established, the differentiations and computations of radii of curvature can proceed in the usual manner.

Curvature of Any Plane Curve

The notations that appear on the plane curve P_oPP' in Fig. 6 are:

- **OP** = position vector that defines point P on a plane curve
- ψ = angle between the position vector when defining point P and the reference direction
- S = arc distance along curved path defined by position vector
- ρ = radius of curvature of path at point P
- **t** = a unit vector, tangent to the path at point P, and known as the unit tangent
- α = angle through which the unit vector **t** turns
- **n** = the unit normal, another unit vector, perpendicular to the unit tangent, and directed toward the center of curvature of the path

From vector analysis or differential geometry, the derivative of the position vector **OP** defining the points along the plane curve P_oPP', Fig. 6, is

$$\frac{d\mathbf{OP}}{d\psi} = \frac{dS_P}{d\psi}\,\mathbf{t}_P \qquad (1)$$

where $dS_P/d\psi$ is the rate at which distance along the curve changes with angle ψ. Since the unit tangent (vector **t**) has a constant magnitude of unity, it does nothing more nor less than define the direction along the curve.

The derivative of the unit tangent with respect to the angle α through which it turns is another unit vector, the unit normal **n**, or

$$d\mathbf{t}/d\alpha = \mathbf{n} \qquad (A)$$

Since the unit vectors **t** and **n** comprise a right-angled pair that rotate simultaneously through angle α in the same direction and at the same rate, the unit normal also has a derivative, namely

$$d\mathbf{n}/d\alpha = -\mathbf{t} \qquad (B)$$

The minus sign is introduced to define the direction of the derivative of the unit normal as being 180 deg out-of-phase with the direction of the unit tangent. This procedure is analogous to the change in sign attached to the trignometric functions between one quadrant and another or to the plus and minus signs of a complex number. These signs are essential if every direction throughout 360 deg about a point is to be defined in terms of the unit vectors **t** and **n**, the unit vectors being regarded as establishing the instantaneous positive directions of motion of the particle.

The fundamental relation of arc dS to radius ρ and angle $d\alpha$ is

$$dS = \rho\, d\alpha, \text{ so that } d\alpha = dS/\rho \qquad (C)$$

hence

$$d\mathbf{t} = \mathbf{n}\, d\alpha = \mathbf{n}\, dS/\rho \qquad (D)$$

Relationships (A) and (D) substituted in the differentiation of Eq (1), the product of a variable scalar and a variable unit vector, with respect to angle ψ yield

$$\frac{d^2\mathbf{OP}}{d\psi^2} = \frac{d^2S}{d\psi^2}\,\mathbf{t} + \frac{1}{\rho}\left(\frac{dS}{d\psi}\right)\mathbf{n} \qquad (2)$$

The expression Eq (2) is general and applies to any plane curve. Since the reciprocal of the radius of curvature is known as the curvature, Eq (2) can be identified as a curvature equation. Needless to say it is also a vector.

Ordinary Slider-Crank Mechanism

All that is needed to put Eq (2) to use for a specific mechanism is to find the vector to which it is identical. From Fig. 1 the position of P can be expressed by the position vector

$$\mathbf{OP} = \mathbf{OA} + \mathbf{AP} = -C\mathbf{n}_A - M\mathbf{r} \qquad (3)$$

In Eq (3), the scalars C and M are constants, the unit vector $\mathbf{n}_A$ varies with θ, and unit vector **r** varies with ϕ. Angle θ is taken as the independent variable in all cases. One differentiation of Eq (3) with respect to angle θ gives

$$\frac{d\mathbf{OP}}{d\theta} = -C\frac{d\mathbf{n}_A}{d\theta} - M\frac{d\mathbf{r}}{d\theta} \qquad (3A)$$

Differentiation of the unit vector $\mathbf{n}_A$ in the manner illustrated by Eq (B) yields

$$-(d\mathbf{n}_A/d\theta) = \mathbf{t}_A \qquad (E)$$

Since unit vector **r** varies with angle ϕ, which in turn is dependent on angle θ,

$$d\mathbf{r}/d\phi = \mathbf{s} \qquad (F)$$

and

$$d\mathbf{r}/d\theta = (d\varphi/d\theta)\,\mathbf{s} \qquad (G)$$

When relations (E) and (G) are substituted into Eq (3A), and Eq (3A) and Eq (1) are equated to eliminate the common derivative of **OP**, the following identity is obtained

$$-\frac{dS_P}{d\theta}\,\mathbf{t}_P \equiv C\mathbf{t}_A - M\frac{d\varphi}{d\theta}\,\mathbf{s} \qquad (4)$$

From the position diagram, Fig. 1, the scalar $d\phi/d\theta$ can be found as follows:

$$\sin\varphi = (C/R)\sin\theta \qquad (5)$$

One differentiation of Eq (5) and the elimination of the functions of

angle ϕ leads to

$$\frac{d\varphi}{d\theta} = \frac{-\cos\theta}{\sqrt{(R/C)^2 - \sin^2\theta}} \qquad (6)$$

The Identity (4) is a vector triangle. All the quantities that make up the vector difference on the right-hand side are known; hence the triangle can be constructed to find the direction $\mathbf{t}_P$ and the magnitude $dS_P/d\theta$. Any closed vector triangle or polygon can be solved whenever not more than two quantities in it are unknown. The two unknowns can be two directions, two magnitudes, or a direction and a magnitude. In Eq (4), the scalar $dS_P/d\theta$ and the unit vector $\mathbf{t}_P$ happen to be the two unknown quantities.

A second differentiation of Eq (3) gives the following identity, in which the radius of curvature ρ, an unknown scalar, appears in the magnitude of one of the vector components.

$$\frac{d^2S_P}{d\theta^2}\,\mathbf{t}_P + \frac{1}{\rho}\left(\frac{dS_P}{d\theta}\right)^2 \mathbf{n}_P \equiv C\mathbf{n}_A - M\frac{d^2\varphi}{d\theta^2}\,\mathbf{s} + M\left(\frac{d\varphi}{d\theta}\right)^2 \mathbf{r} \qquad (7)$$

The scaler $d^2S_P/d\theta^2$ is a second unknown, consequently all the other quantities of Identity (7) must be found to render the Identity determinate and solvable.

All five directions, namely $\mathbf{n}_A$, $\mathbf{s}$, $\mathbf{r}$, $\mathbf{t}_P$ and $\mathbf{n}_P$ are known or knowable. The direction of unit vector $\mathbf{t}_P$ is established by the solution of Identity (4) and $\mathbf{n}_P$ is perpendicular to $\mathbf{t}_P$. The scalar $(dS_P/d\theta)^2$ is also knowable by the solution of Identity (4). The scalar $d\phi/d\theta$ is found from Eq (6).

The scalar $d^2\phi/d\theta^2$ is found by differentiating Eq (6) or

$$\frac{d^2\varphi}{d\theta^2} = \frac{[(R/C)^2 - 1]\sin\theta}{[(R/C)^2 - \sin^2\theta]^{3/2}} \qquad (8)$$

Construction of the vector polygon defined by Identity (7) is a simple way of finding the magnitudes of its two unknown scalars ρ and $d^2S_P/d\theta^2$. The three components on the right are compounded to form a resultant vector, after which this resultant is resolved into two vectors having the directions $\mathbf{t}_P$ and $\mathbf{n}_P$. This procedure fixes the magnitude of scalar $(dS_P/d\theta)^2/\rho$. The quantity $dS_P/d\theta$ is known from the solution of Identity (4); hence ρ can be computed.

The foregoing direction and curvature identities are given in Table I for the ordinary slider-crank along with those for each of the three inversions of the basic mechanism. The Identities are vector sums or differences. Naturally these vector sums or differences are applicable only when used in conjunction with the particular position diagram for which they have been derived.

Both the locus described by P and its evolute are shown in Fig. 1 for half a revolution of the crank.

Fixed-Slider Mechanism

Since one link-constraining point of crank C of the fixed-slider mechanism, shown in Fig. 2, has rectilinear motion while the other moves in a circular arc, the angular rates $d\phi/d\theta$ and $d^2\phi/d\theta^2$ for this mechanism are equal to those of an ordinary slider-crank mechanism of equal dimensions. These magnitudes therefore can be found from Eqs (6) and (8) for any desired angular position of the mechanism. The position equation, on the other hand, is a little different. The position equation for the fixed-slider mechanism is stated in column 3 of Table I, along with the direction vector and curvature vector.

An example will illustrate the details of finding radii of curvature by semi-graphical methods. Table II shows the position diagram at that station in the cycle of motion when θ equals 30 deg. This station is called one and is denoted by the subscripts one, for example, A_1, O_1, and B_1.

Link R is taken as 7 in. long; crank AB as 2.5 in. with the center of gravity P one inch from A. These dimensions substituted into Eq (6) for the 30 deg station make

$$d\varphi/d\theta = -0.315$$

Substituting these known quantities into the Direction Identity of column 2, Table I, gives

$$(dS_P/d\theta)\,\mathbf{t}_P \equiv 1.57\,\mathbf{t}_P \equiv -2.25\mathbf{s} - \mathbf{t}_{AB} \qquad (H)$$

The construction to get the magnitude $dS_P/d\theta$ equals 1.57 and the direction $\mathbf{t}_P$ consists merely of adding the two vectors on the right side of the Identity (H) to get the resultant, vector $\mathbf{o}_1\mathbf{p}_1$. Note that the 2.2 in. is laid off from the convenient origin o_1 in the direction opposite to positive $\mathbf{s}$; this takes care of the minus sign. For the same reason, the one-inch magnitude and coefficient of $\mathbf{t}_{AB}$ is laid off in the direction opposite to that in which A moves relative to B. Vector $\mathbf{o}_1\mathbf{p}_1$ is measured to get the wanted magnitude $dS_P/d\theta$ equals 1.57.

Much the same procedure is used in the graphical solution of the Curvature Identity, Table I, column 3. When the knowable magnitudes are found and substituted into it, there is obtained a resultant vector

$$\mathbf{o}'_1\mathbf{p}'_1 = -\mathbf{n}_{AB} - 0.68\mathbf{r} + 1.145\mathbf{s} \qquad (I)$$

The composition of this resultant vector is illustrated in the right-hand column of Table II. The same vector diagram also illustrates the resolution

Table I—Direction and Curvature Identities Associated With Position Diagrams

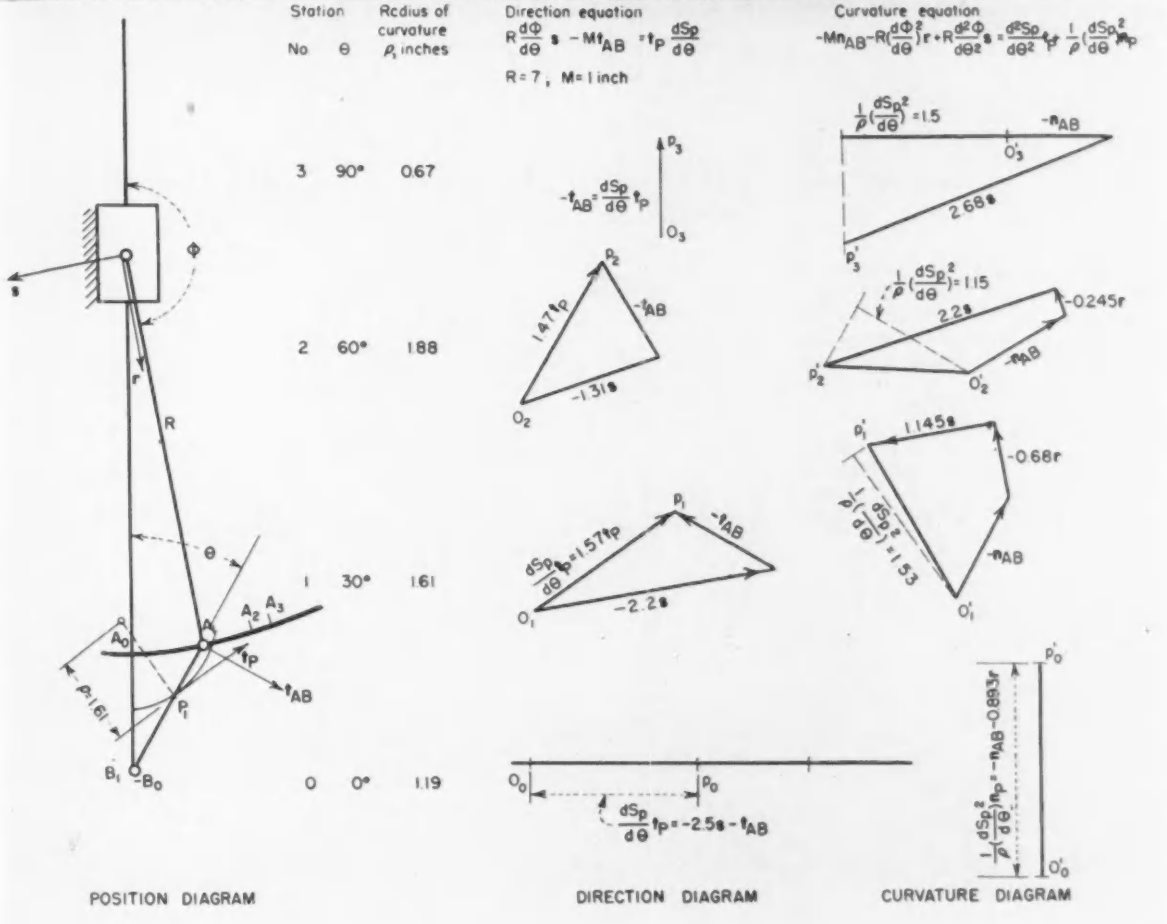
Position Diagram	Fig 1	Fig 2	Fig 3	Fig 4
Position Vector $\mathbf{OP} \equiv$	$-Cn_A - Mr$	$Rr + Mn_{AB}$	$-Cn_Q - Mr$	$-Cn_A - Mr$
Direction Identity $\frac{dSp}{d\theta}\,t_P \equiv$	$Ct_A - M\frac{d\Phi}{d\theta}s$	$R\frac{d\Phi}{d\theta}s - Mt_{AB}$	$Ct_Q - M\frac{d\Phi}{d\theta}s$	$Ct_A - M\frac{d\Phi}{d\theta}s$
Curvature Identity $\frac{d^2Sp}{d\theta^2}t_P + \frac{1}{\rho}\left(\frac{dSp}{d\theta}\right)^2 n_P \equiv$	$Cn_A - M\frac{d^2\Phi}{d\theta^2}s + M\left(\frac{d\Phi}{d\theta}\right)^2 r$	$R\frac{d^2\Phi}{d\theta^2}s - R\left(\frac{d\Phi}{d\theta}\right)^2 r - Mn_{AB}$	$Cn_Q - M\frac{d^2\Phi}{d\theta^2}s + M\left(\frac{d\Phi}{d\theta}\right)^2 r$	$Cn_A - M\frac{d^2\Phi}{d\theta^2}s + M\left(\frac{d\Phi}{d\theta}\right)^2 r$

Table II—Graphical Method of Finding Radii of Curvature at Four Stations in a Cycle of Motion

Station No	θ	Radius of curvature ρ, inches
3	90°	0.67
2	60°	1.88
1	30°	1.61
0	0°	1.19

Direction equation $R\frac{d\Phi}{d\theta}\mathbf{s} - Mt_{AB} = t_P\frac{dS_P}{d\theta}$, R = 7, M = 1 inch

Curvature equation $-Mn_{AB} - R(\frac{d\Phi}{d\theta})^2\mathbf{r} + R\frac{d^2\Phi}{d\theta^2}\mathbf{s} = \frac{d^2S_P}{d\theta^2}t_P + \frac{1}{\rho}(\frac{dS_P}{d\theta})^2 n_P$



of resultant vector $\mathbf{o'}_1\mathbf{p'}_1$ into components parallel to unit vector $\mathbf{t}_P$ and $\mathbf{n}_P$, respectively. The magnitude of the component parallel to $\mathbf{n}_P$, namely $(dS_P/d\theta)^2/\rho$ equals 1.53, contains the wanted radius of curvature ρ. Since $dS_P/d\theta$ equals 1.57, ρ is readily computed as 1.61 inches.

To get the radius of curvature at some other station, as station No. 2, the position diagram is constructed so as to establish the directions of the unit vectors at that position in the cycle of motion, and the foregoing procedure repeated. Table II illustrates the direction and curvature polygons at three other stations, including the zero and 90 deg positions. The method is valid for any station in a cycle of motion. Furthermore, the method is applicable to any plane-motion mechanism. The evolutes of Figs. 1, 3 and 4 were found by repeated application of the foregoing analyses and procedure.

Inversions of Slider-Crank Mechanism

Kinematically, a rigid body restricted to plane motion has three degrees of freedom. Three coordinates, or the equivalent thereof, are necessary and sufficient to constrain a rigid body in plane motion so as to be usable as a machine element. Two directions and a distance embrace these three coordinates in the case of the link containing P for each of the four mechanisms discussed here.

In the mechanisms shown in Figs. 1 and 2, the constant direction of the slider defines the path of one body-constraining point in the floating link. In inversions Figs. 3 and 4, the variable direction of the slider does not transfer a known path of motion to the adjacent link. Only the angle relationship is maintained; this relationship is expressed by the following equation

$$\frac{\sin\varphi}{C} = \frac{\sin(\varphi - \theta)}{R} \qquad (9)$$

Two differentiations of Eq (9) and the elimination of the functions of ϕ yield

$$\frac{d\varphi}{d\theta} = \frac{1 - (R/C)\cos\theta}{1 + (R/C)^2 - 2(R/C)\cos\theta} \qquad (10)$$

and

$$\frac{d^2\varphi}{d\theta^2} = \frac{[(R/C)^2 - (R/C)]\sin\theta}{[1 + (R/C)^2 - 2(R/C)\cos\theta]^2} \qquad (11)$$

Values of these angular magnitudes substituted into the direction vectors and curvature vectors in columns 4 and 5, Table I, lead to the radii of curvature of inversions, Fig. 3 and 4, in which are shown the evolutes of each inversion over half a cycle.

This analysis has focussed attention on a method of finding a radii

Fig. 7—Magnitude of rate $d\phi/dt$ for inversions in which the slider oscillates; rates at crank angles are given for several R/C ratios.

Fig. 8—Magnitude of rate $d\phi/dt$ for the ordinary slider-crank mechanism and its inversion with the slider fixed; rates at crank angles are given for several R/C ratios.

Fig. 9—Angular rate $d^2\phi/d\theta^2$ for the ordinary slider-crank mechanism and its inversion with the slider fixed; rates at crank angles are given for several R/C ratios.

Fig. 10—Angular rate $d^2\phi/d\theta^2$ for inversions in which the slider oscillates; rates at crank angles are given for several R/C ratios.

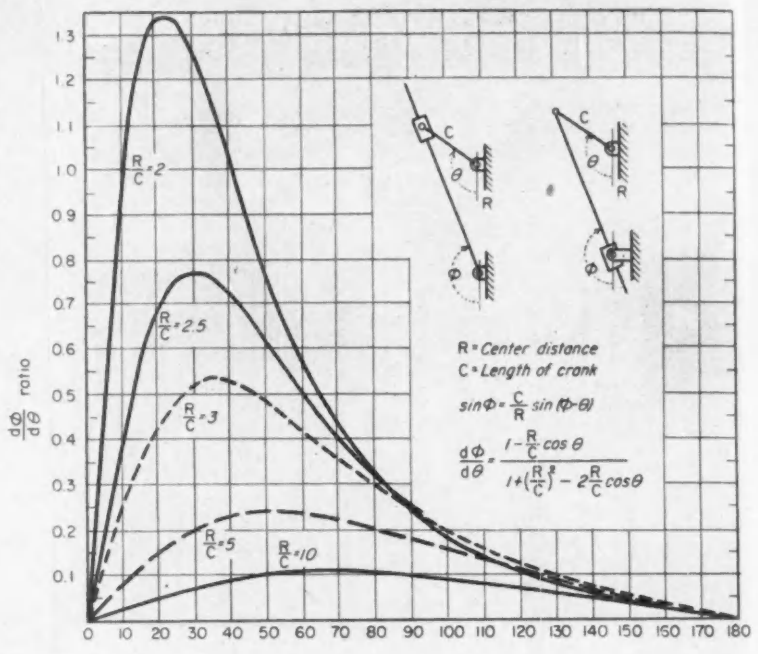


Fig. 7

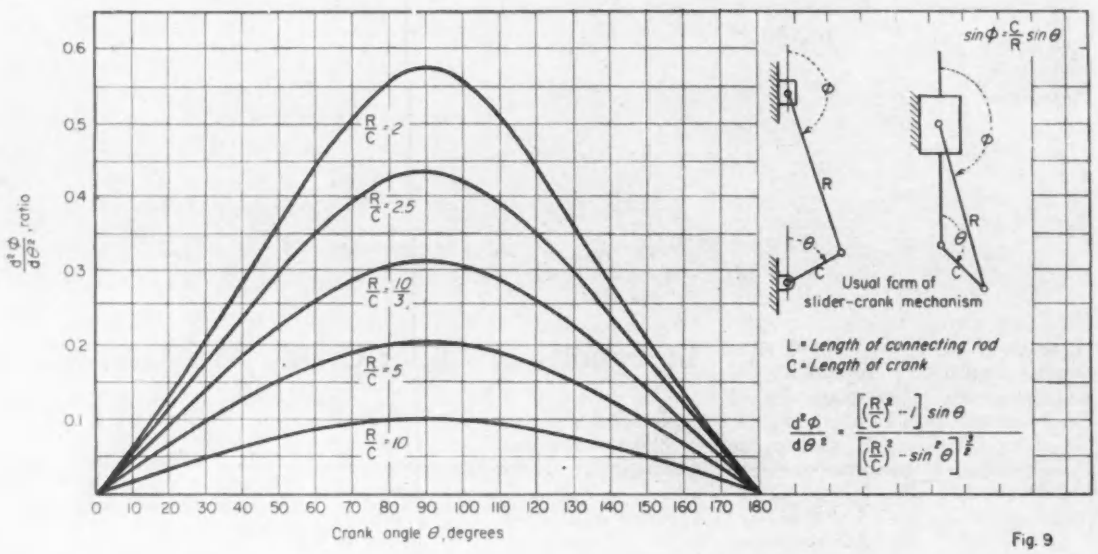


Fig. 9

of curvature of a locus described by any particle in the plane-motion slide-crank mechanism. There are other by-products of the methods. For example, angular speeds are defined directly by Eqs (6) and (10); and the use of Eqs (10) and (11) obviates the finding of the Coriolis' component when the accelerations of particles in links Z of Figs. 2 and 3 are wanted.

Other Slider-Crank Mechanisms

Charts of angular magnitudes defined by Eqs (6), (8), (10) and (11) facilitate the extension of the graphical methods to slider-crank mechanisms of other ratios. Such charts plotted for a few values of the ratio R/C are shown in Figs. 7, 8, 9 and 10. Since such charts give only rough approximations when subjected to interpolation, in-between ratios are needed for complete coverage.

As already pointed out, these charts are not restricted to the single use of finding radii of curvature. One property charts such as these do reveal quite prominently are the stations of maximum and minimum angular magnitudes.

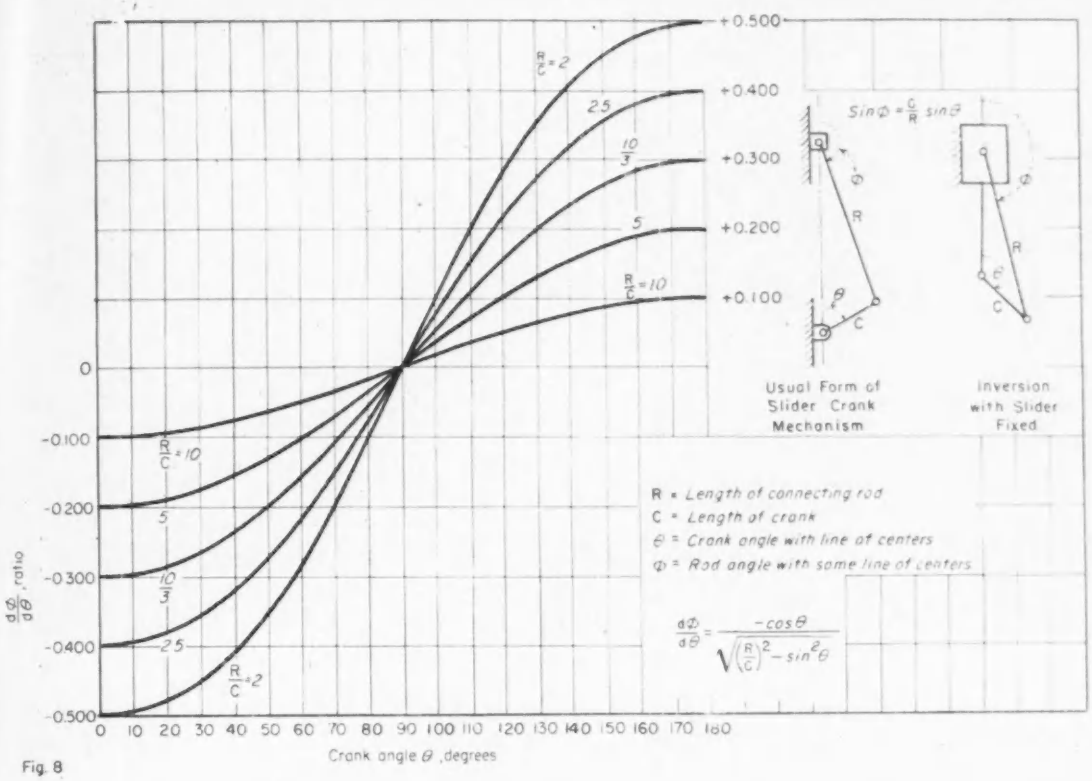


Fig. 8

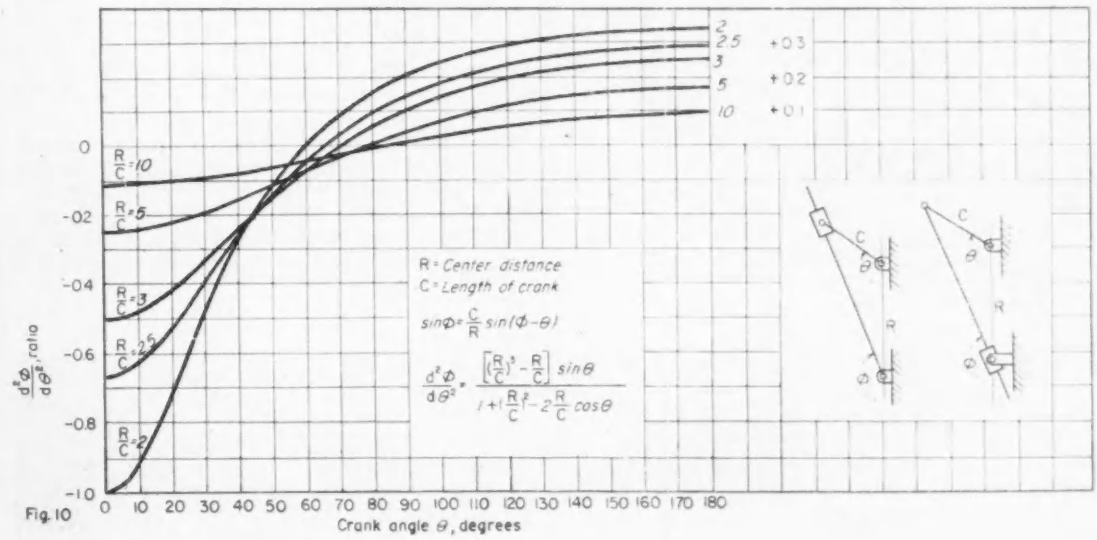
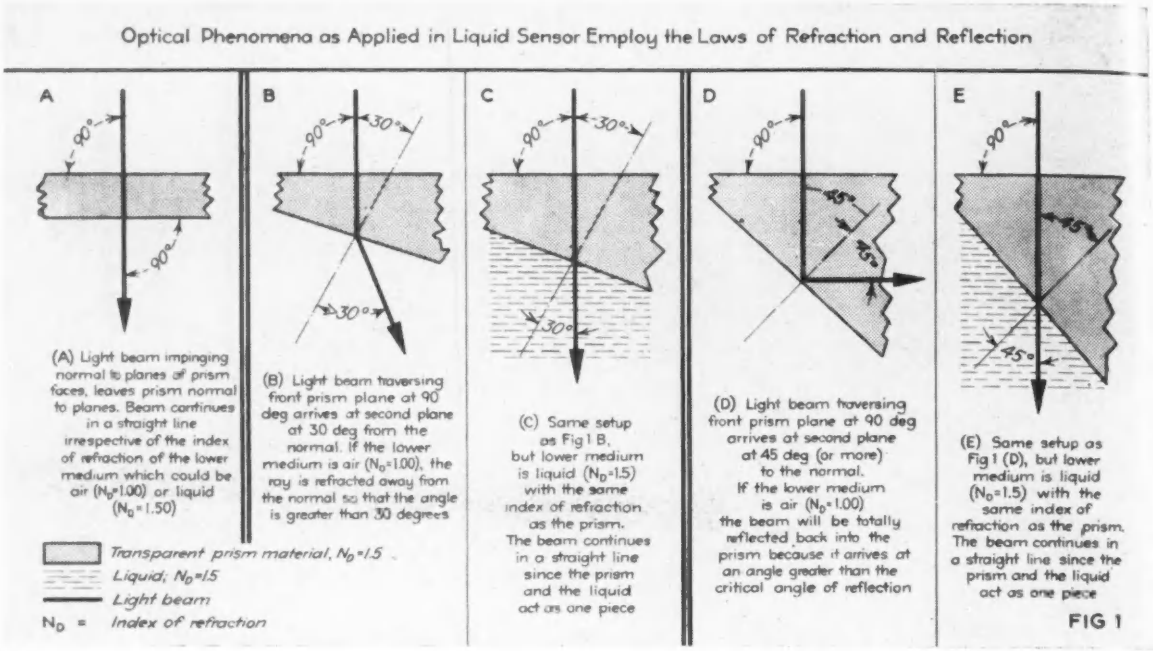


Fig. 10

Analytical Methods

Graphical methods are usually adequate when velocities and accelerations in machines are wanted to solve problems in kinetics of machinery. As already explained, Eq (2) applies to any plane curve; so does the method of establishing the position vector. Accordingly, similar methods can be used to find radii of curvature on cams, gear teeth, and of the paths traced by particles in other mechanisms. Nevertheless graphical methods, like slide rules, do not provide sufficient accuracy for every kind of design calculation, particularly those pertaining to the generation of gear teeth or precision cams, therefore, analytical methods become necessary for such design.

To get equations for analytical solutions, each vector identity, as Eq (4), can be transformed into two equivalent scalar equations. The mathematical manipulation is lengthy but not impossible. In any event, a parallel solution by graphical methods reveals just what takes place in the moving mechanism and also provides a rough check on numerical results.


Optical Phenomena as Applied in Liquid Sensor Employ the Laws of Refraction and Reflection
A
B
C
D
E
90°
30°
45°
(A) Light beam impinging normal to planes of prism faces, leaves prism normal to planes. Beam continues in a straight line irrespective of the index of refraction of the lower medium which could be air (N_D=1.00) or liquid (N_D=1.50)
(B) Light beam traversing front prism plane at 90 deg arrives at second plane at 30 deg from the normal. If the lower medium is air (N_D=1.00), the ray is refracted away from the normal so that the angle is greater than 30 degrees
(C) Same setup as Fig 1 B, but lower medium is liquid (N_D=1.5) with the same index of refraction as the prism. The beam continues in a straight line since the prism and the liquid act as one piece
(D) Light beam traversing front prism plane at 90 deg arrives at second plane at 45 deg (or more) to the normal. If the lower medium is air (N_D=1.00) the beam will be totally reflected back into the prism because it arrives at an angle greater than the critical angle of reflection
(E) Same setup as Fig 1 (D), but lower medium is liquid (N_D=1.5) with the same index of refraction as the prism. The beam continues in a straight line since the prism and the liquid act as one piece
Transparent prism material, N_D=1.5
Liquid; N_D=1.5
Light beam
N_D = Index of refraction
FIG 1

Liquid Sensing Device With No Moving Parts

DELL PHILLIPS
Vice President, Wm. R. Whittaker Co., Ltd.

EVEN ELECTRICAL DEVICES that sense the presence or absence of liquids contain moving parts that restrict their use in applications subject to vibration and shock. Also, malfunctioning may occur as a result of clogging or corrosion of these operating parts.

One ingenious liquid sensor that has no moving parts was developed by using simple principles of optics and a small electric current. The device controls liquid levels and detects the presence or absence of liquid in closed lines or tanks, even under severe shock and vibration. Familiar laws of reflection and refraction are employed to eliminate diaphragms, floats, and other related devices and to produce a detector that is small, simple, compact and foolproof.

Optical phenomena as applied to these units are illustrated in Fig. 1. Components include light source, prism and photo cell. A beam of light is projected into a

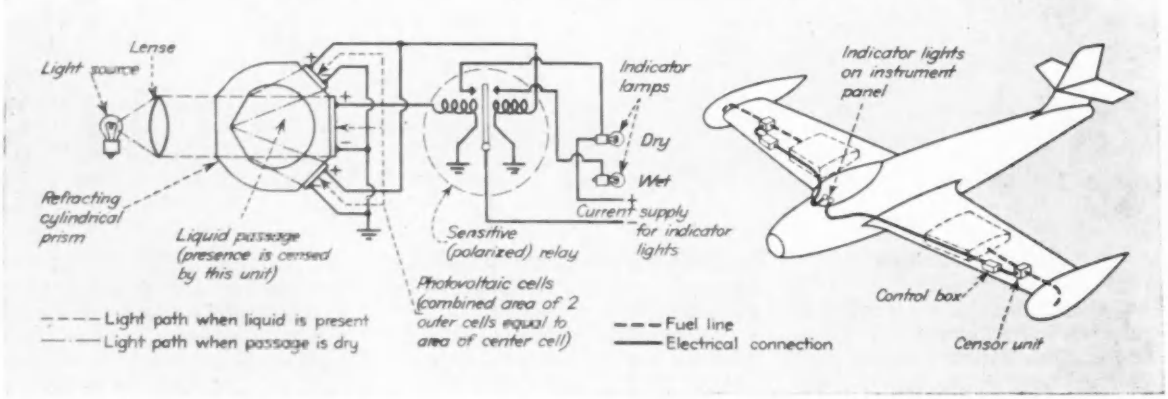
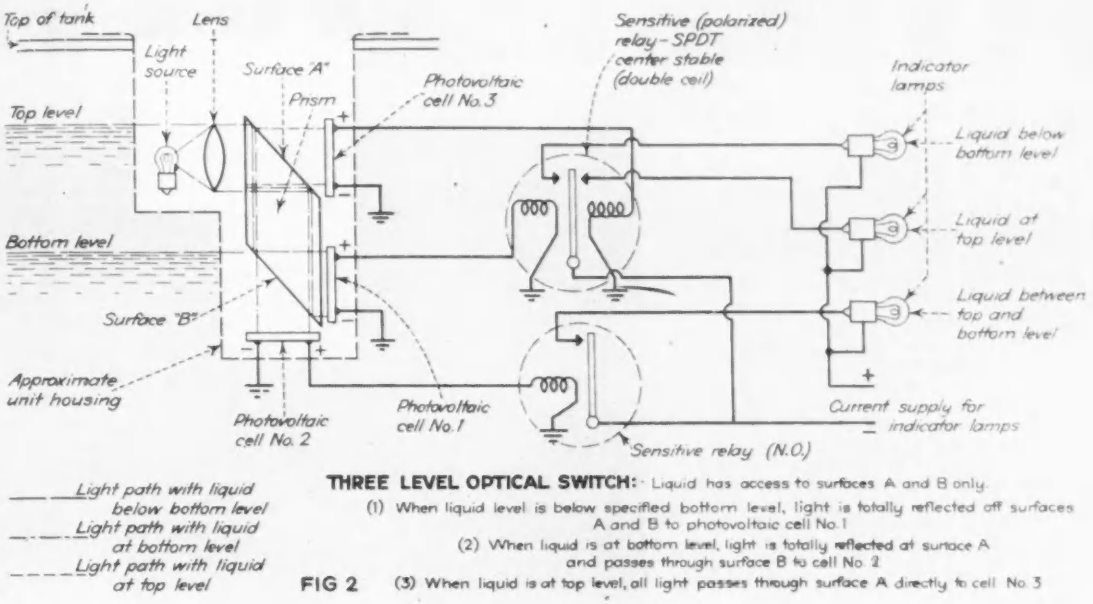


Fig. 3—Optical device designed to sense presence of aromatic fuel in aircraft fuel line. It determines the exact moment when wing-tip tanks are empty and ready to be dropped. Unit illustrated indicates condition of tanks with warning lights; it could be wired to control or actuate secondary equipment that would automatically switch to another tank or drop the empty tank. (Right) Schematic sketch of the installation of liquid sensor in an airplane. Shock and vibration do not affect operation of device.



THREE LEVEL OPTICAL SWITCH: Liquid has access to surfaces A and B only.

(1) When liquid level is below specified bottom level, light is totally reflected off surfaces A and B to photovoltaic cell No. 1

(2) When liquid is at bottom level, light is totally reflected at surface A and passes through surface B to cell No. 2

(3) When liquid is at top level, all light passes through surface A directly to cell No. 3

FIG 2

prism whose index of refraction is very close to that of the liquid being sensed and whose surface is located at the critical liquid level. If liquid is present at the surfaces of the prism, the liquid and the prism act as one piece and the light moves through the prism unaffected; if liquid is absent, the light is totally reflected inside the prism, or refracted out of the prism. Voltaic cells, located to pick up light after it passes through the prism, convert the light to electrical energy that controls or actuates secondary equipment.

Small changes in the index of refraction of the media, both prism and liquid, do not affect operation to a great degree. As an example, in Fig. 1 (*C*) if the index of refraction of the liquid were 1.4 and that of the prism 1.5 (instead of 1.5 and 1.5) the beam would be deviated $2\frac{1}{2}$ degrees. It would slope slightly down to the right instead of being vertical. This error might be serious in large units. But when the liquid's index of refraction is known in advance, the prism material can be tailored to give the closest possible indices and reduce errors to infinitely small values. The only limitations affecting the function of this type device are: (1) reasonable transparency of the liquid to be sensed; (2) index of refraction of the liquid must be between 1.25 and 1.55 (this includes most liquids—water, gasoline, aromatic fuels, light oils, etc).

Residue of liquid left on the reflecting or refracting surface of the device has little effect on operation. This contamination does not reduce the light transmission appreciably when the surface is wet; and most residues have a sufficiently low index of refraction so that they cause only minor efficiency loss when the surface is dry. Pictured on these pages are typical applications of liquid sensing devices.

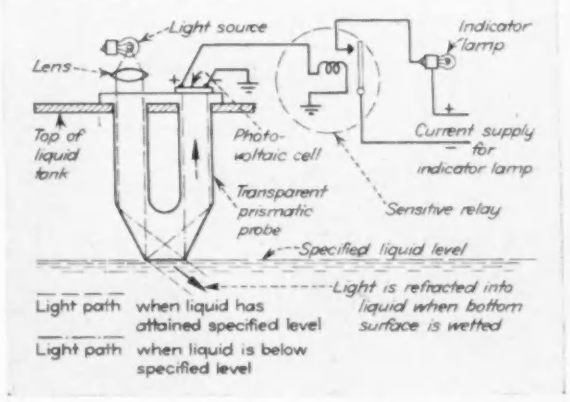

Light source
Indicator lamp
Lens
Top of liquid tank
Photo-voltaic cell
Current supply for indicator lamp
Transparent prismatic probe
Sensitive relay
Specified liquid level
Light is refracted into liquid when bottom surface is wetted
Light path when liquid has attained specified level
Light path when liquid is below specified level

Fig. 4—Optical high-level switch. When fuel falls below the specified level, light is reflected into voltaic cell. Relay is activated and warning lamp lights. When level is satisfactory, light is refracted into liquid and does not reach photo cell.

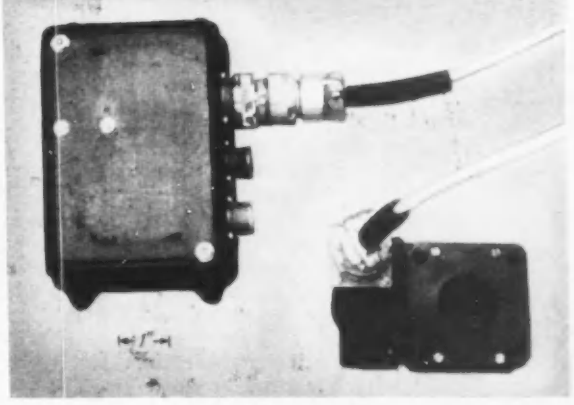
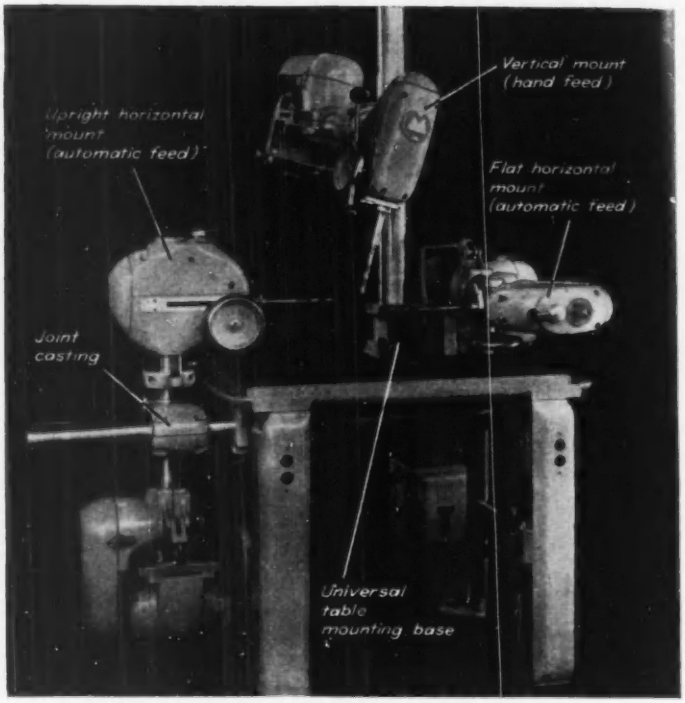


Fig. 5—Photograph of typical optical switch. Light source, lens, prism and photo-voltaic cells are in main unit (right). All other equipment such as relays, indicator light and power supply inlets-plugs are contained in a separate box (left).

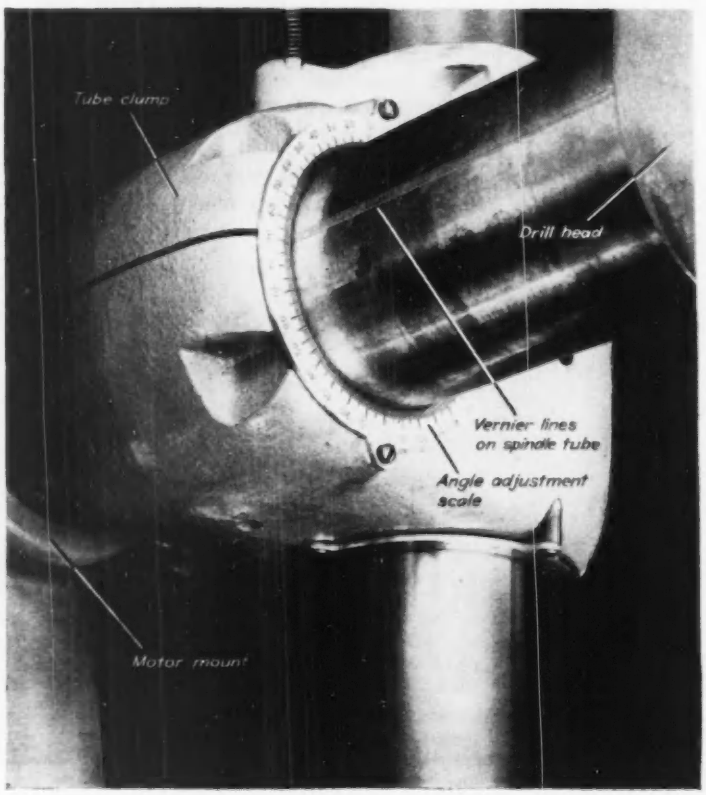
DESIGN FEATURES

Spring Loaded Worm Gear Makes Feed on Drill Press Pressure Sensitive


Vertical mount (hand feed)
Upright horizontal mount (automatic feed)
Flat horizontal mount (automatic feed)
Joint casting
Universal table mounting base

THE DRILL PRESS consists of a standardized individually powered drill head with a mounting system of ground steel tubes and joint castings. Drilling angle can be accurately adjusted by use of a vernier scale on the tubes and protractors on the joint casting. Both vertical and horizontal mounting tubes have angular adjustment scales.

POWER FEED DRIVE. When quill feed reaches the limit of the depth control setting or when sufficient resistance to feed travel is encountered (hard spot in material or dull drill) rotation of the gears will be stopped. Additional power input forces the spring loaded worm drive to ride up on the splined shaft actuating the toggle linkage that disengages the idler gear in the carriage from the quill rack drive gear. By pressing the start button or energizing the solenoid, the carriage will be returned to the re-engaged position by the actuating spring.



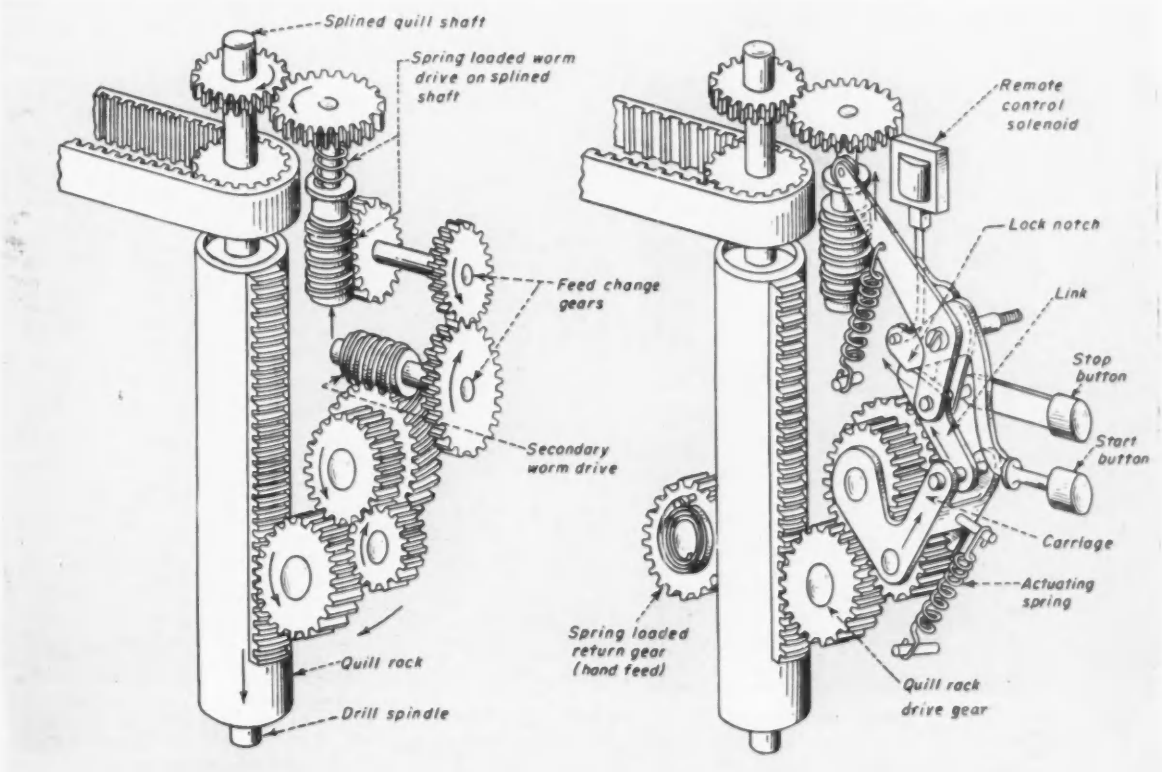
IN NEW PRODUCTS

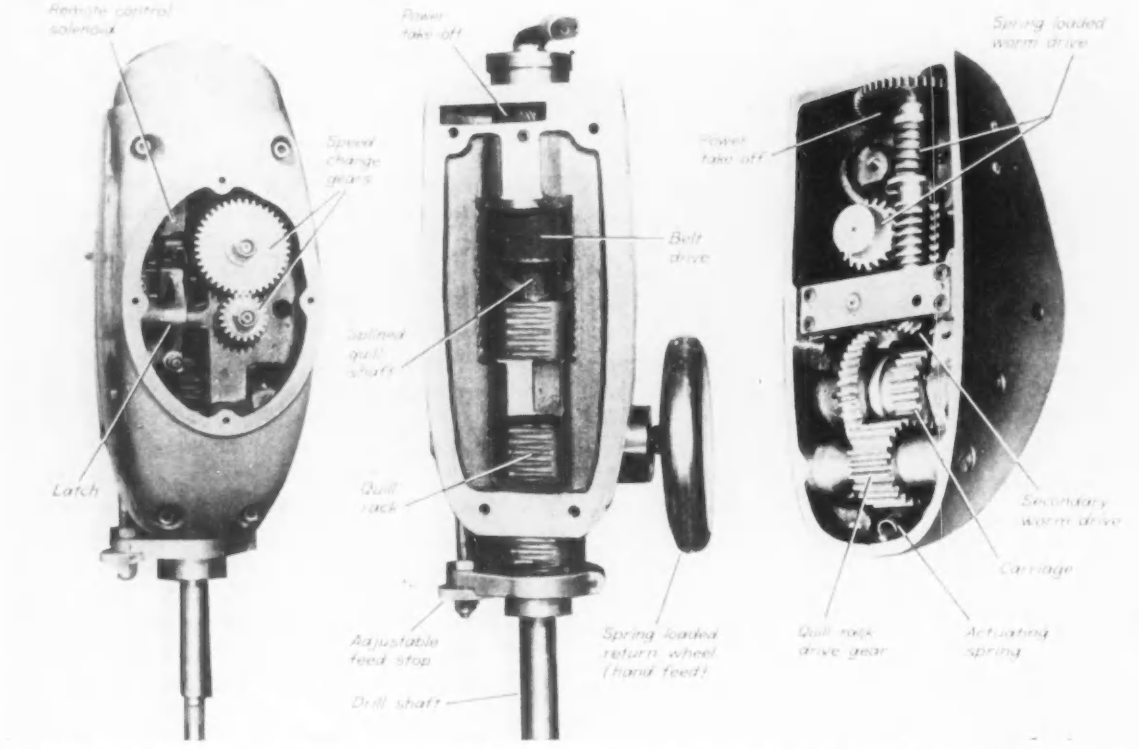
In the power feed gear train of this drill press is a spring loaded worm gear that will disengage the final drive gears of the power feed when resistance of predetermined magnitude interferes with normal drill spindle advance. The resistance can be exerted either by excessive drill point pressure (dull drill or hard spot in work) or when the drill spindle reaches the extent of its travel as set on the depth stop screw.

When the quill rack advance is stopped by one of these actions the power feed gears are locked but power input continues. This causes the worm gear to ride up on a splined shaft against an adjustable spring. As it is displaced it carries with it a shift lever that releases the final drive feed gears from engagement. Then the quill rack is free to be retracted by the spring loaded pinion of the conventional hand feed. Complete disengagement allows a 3 revolution dwell. The worm gear spring can be adjusted for drill point loads of from 100 to 1,000 lb. The power feed gears can be reengaged by a manual control or an electric solenoid provided for remote or simultaneous control of multiple heads. It can be set for continuous cycling and for manual over-feed to power engagement at any depth.

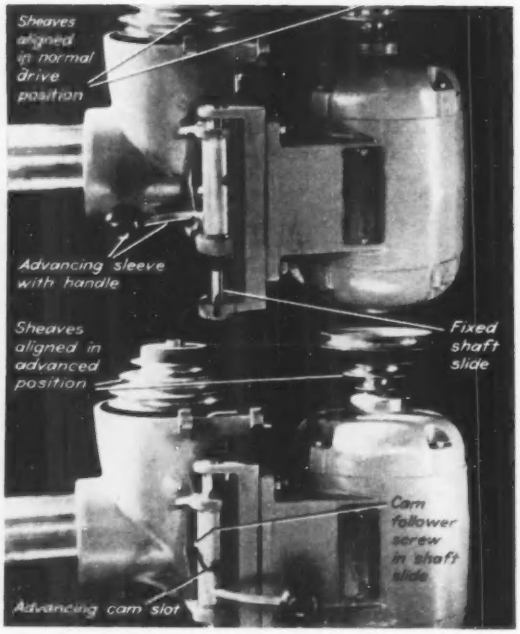
The Magna Drill on which this power feed is used, is made by Magna Engineering and it has a capacity of one inch in cast iron and $\frac{3}{4}$ in. in steel. Feed stroke is five inches and the throat is adjustable from $6\frac{1}{2}$ in. minimum to 14 in. maximum. Clearance is 32 in. under the spindle tip. The narrow head permits drilling to 6 inch centers on multiple setup. By opposing spindles horizontally, "0" centers can be attained.

Each head has its own 1 hp motor. A cam actuated motor mount makes available 7 speeds ranging from 251 to 6,860 revolutions per minute.

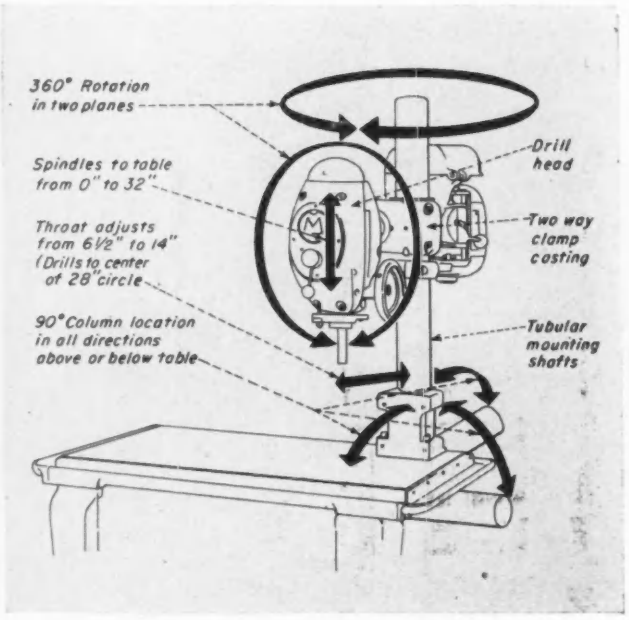




ARRANGEMENT OF ELEMENTS in power feed gear train. Interchangeable feed change gears make possible feed ratios for 0.0025, 0.005, 0.008, 0.012 in. per spindle revolution. Helical power take-off gears are used for quiet operation. At right is shown a rear view of the power feed head with a compound worm gear drive. Here can be seen the square section thrust control spring of the spring loaded worm drive mounted on its splined shaft.


Sheaves aligned in normal drive position
Advancing sleeve with handle
Fixed shaft slide
Sheaves aligned in advanced position
Cam follower screw in shaft slide
Advancing cam slot

CAM SLOTTED SLEEVE on motor mount repositions the sleeves of the V-belt drive to permit three extra speed ratios. This makes available 7 speeds.


360° Rotation in two planes
Drill head
Spindles to table from 0" to 32"
Two way clamp casting
Throat adjusts from 6½" to 14" (Drills to center of 28" circle
90° Column location in all directions above or below table
Tubular mounting shafts

UNIVERSAL POSITIONING of the drill head is made possible by use of tubular mounting shafts and clamp castings. Heavy arrows indicate the range of adjustment available.

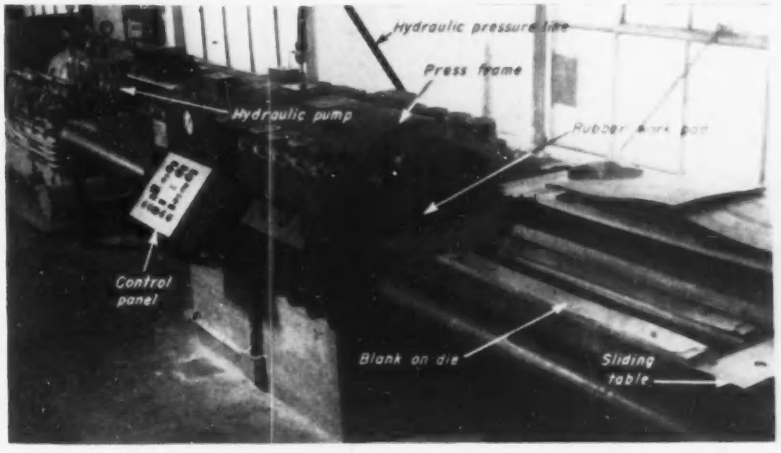
Direct Fluid Action Forms Sheet Metal

This new hydro-press, for forming sheet metal airplane parts, uses a method of applying direct hydraulic pressure to the work being formed. The blanks, from which the parts are to be formed, are placed over simple male dies, positioned in the hydro-press frame, and forming pressure is applied by hydraulically inflating a rubber bladder mounted in the immobile roof of the press.

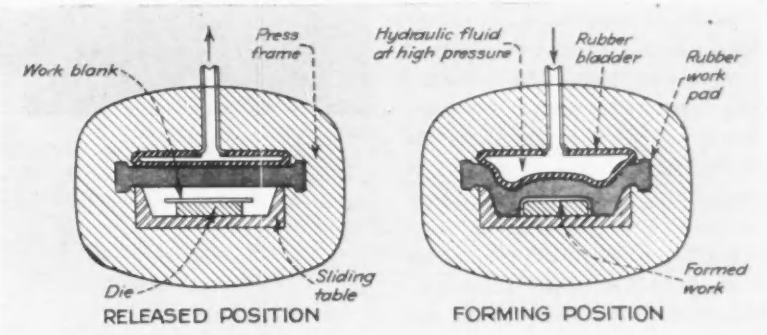
Power to operate the press comes from a double delivery high-low pressure pump driven by a 30 hp motor. Both pressures are used together to inflate the fluid cell. On reaching a predetermined pressure both circuits are automatically unloaded and the cell decompresses through a surge valve. Then the low pressure circuit is ported to impose a vacuum in the supply line and withdraws the remaining oil from the cell, lifting the rubber work pad from the formed part. A vacuum switch senses when the pad is lifted clear and energizes the table moving circuit.

The new press is one-tenth the size of conventional ram type presses yet capable of exerting up to three times the pressures. The higher pressures make possible the forming of heavier gage metals and reduces the amount of secondary hand forming about 50 percent.

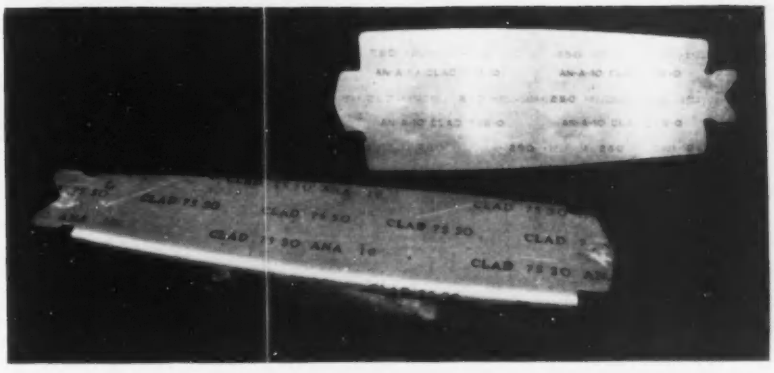
Developed by O. A. Wheelon, production design engineer of the Douglas Aircraft Company, Inc., Santa Monica, Calif., the new machine is suitable for shallow forming of aluminum and other metals used not only in the aircraft industry but in other metal industries as well.



ONLY MOVING PARTS of the forming press are the tables that position the blanks under the hydraulically inflated bladder in the press frame. The double pressure control circuit is electrically interlocked so that: (a) the tables will not move unless bladder is deflated; (b) the tables cannot collide under the frame; (c) the bladder cannot be inflated unless a table is in the frame.



ACTION OF THE FLUID CELL in the forming process. With the work positioned on its die under the work pad, hydraulic oil from the pump is introduced into the rubber fluid cell. The pressurized oil inflates the bladder, which displaces the work pad and bends the work to suit the die. At a predetermined pressure, an unloading valve relieves the pressure in the fluid cell and a partial vacuum is introduced to remove the fluid and return the work pad to normal. Then the sliding table draws the finished part out of the frame.



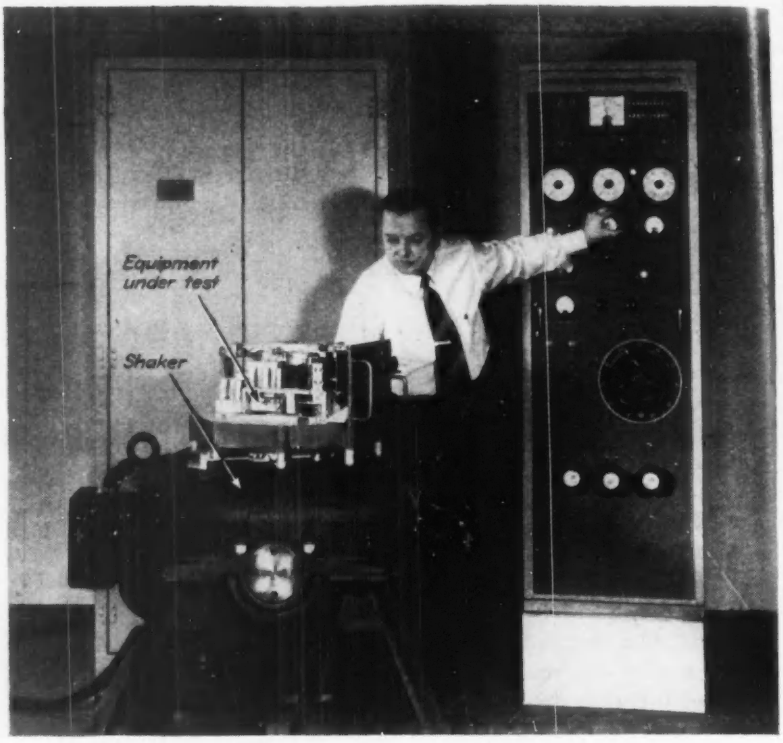
HEAVY GAGE SHEET METAL PARTS formed on the direct acting hydropress. At top is the metal blank, pre-cut from quarter-inch 75s aluminum alloy. At bottom is the part as it comes from the press. Notice the uniform curvature of the bend that was produced by direct action of the high pressure fluid cell.

Shaker Table Mounted on Metal Straps

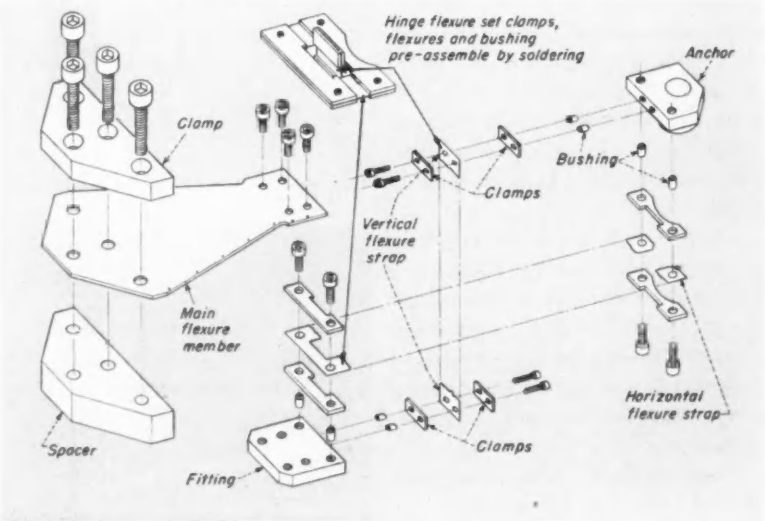
Internal damage, caused by its own action, is prevented in this vibration testing machine by securely mounting together all the adjacent parts. At no time during normal operation does a moving part contact a stationary part. The vibrating table-armature assembly is supported on a system of spring type beams and straps. The four flexure members, in which the beams and straps are used, firmly locate the assembly and bend to permit movement. Spring action of the beryllium copper flexures actually assist in the action of the machine and are used as electrical conductors to carry current to the armature coil.

The shaker, made by the Calidyne Company, Winchester, Mass., works by introducing a conductor with a-c current into the field of a d-c magnet. The direction of the resultant force on the conductor is in accordance with the instantaneous direction of a-c flow and the force is reversed according to current frequency. A power source is used with this unit to induce variable frequencies from 0-500 cps into the armature coil at sufficient current to produce 2,500 lb of force.

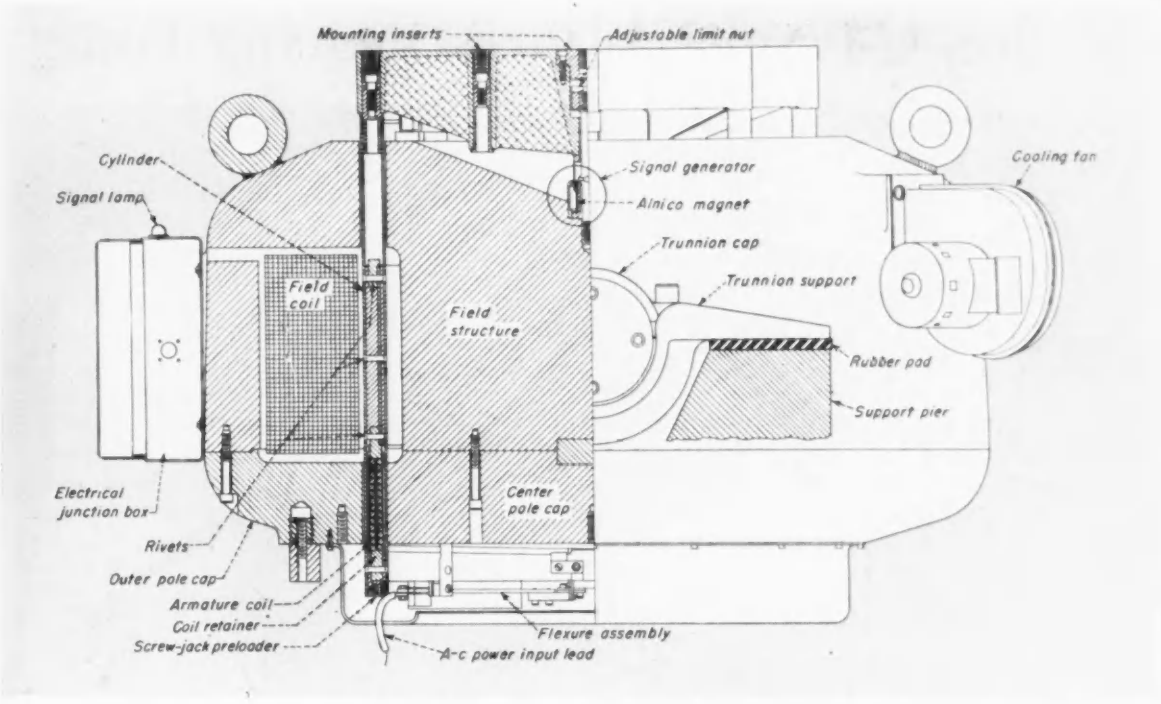
The shaker weighs 3,600 lb. and is mounted at its center of gravity. Rubber isolator pads of special design, made by Connecticut Hard Rubber Company, New Haven, Conn., are used under the trunnion to isolate vibration from the surrounding area.



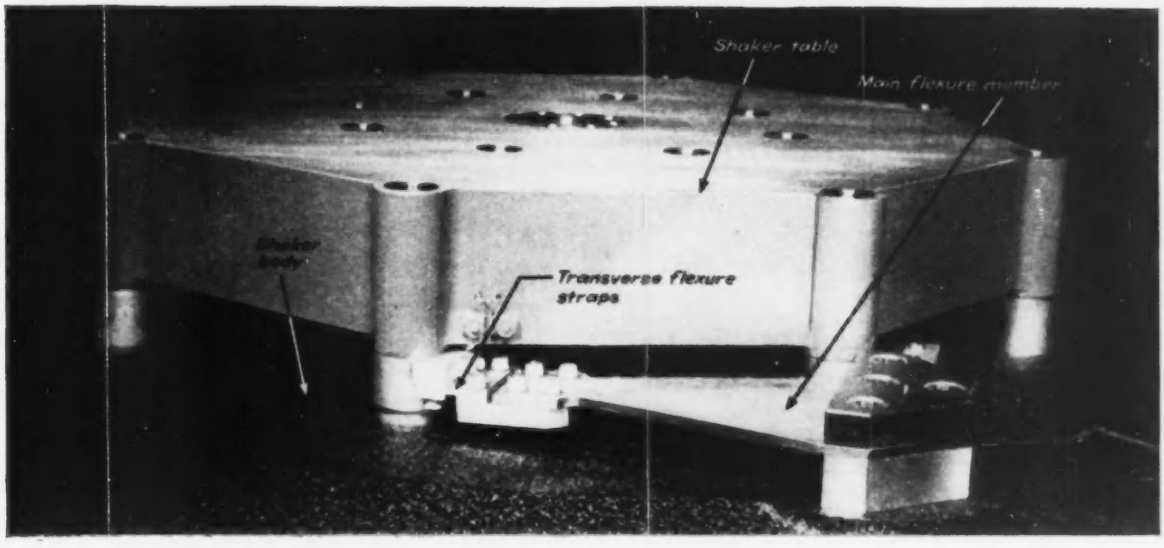
SHAKER with a section of electronic equipment mounted on the table and ready for a vibration test. The shaker can be rotated on its trunnion to permit oscillations in any direction from vertical to horizontal. Forces of 2,500 lb at frequencies up to 500 cps are obtainable. Four fans direct cooling air through the shaker when it is operating.



EXPLODED VIEW of a flexure member shows the interlocked design of the vertical and horizontal flexure straps. The vertical straps carry the vibratory load in compression as well as tension. The horizontal straps maintain the position of the table-armature coil assembly in the field structure. All the flexure members are beryllium copper.

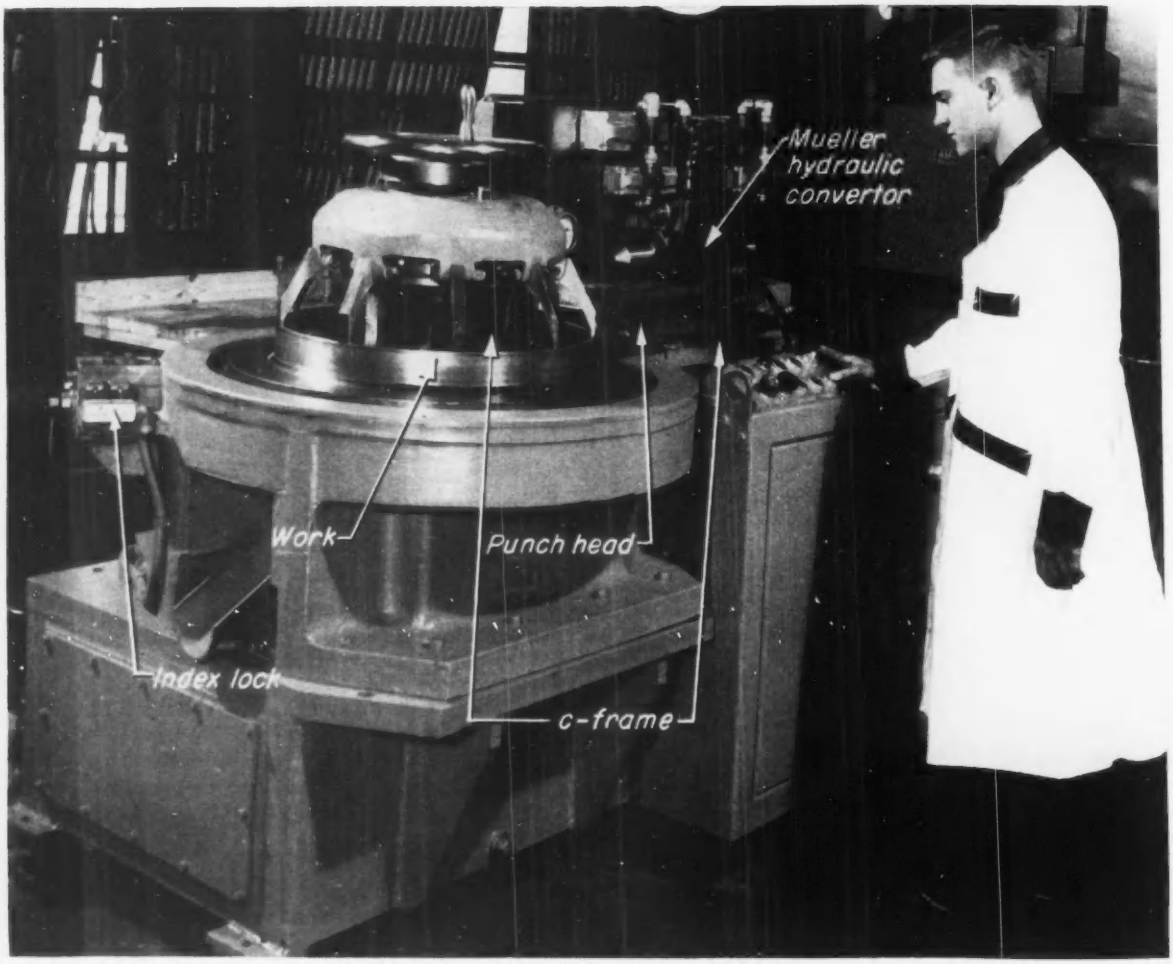


SHAKER TABLE is mounted on eight through-rods that are slotted from the bottom up to receive the cylindrical mounting ring and the armature coil. Rivets hold the assembly together. The wires of the armature coil are set in a double helix groove in the coil retainer, and the coil assembly is firmly supported by a screw-jack preloader that assures no-play during destructive battering under vibratory loads. The signal generator uses a fine wire coil that passes through the field of a permanent magnet during operation. Frequency and magnitude of the current thus produced gives a direct indication of shake performance.

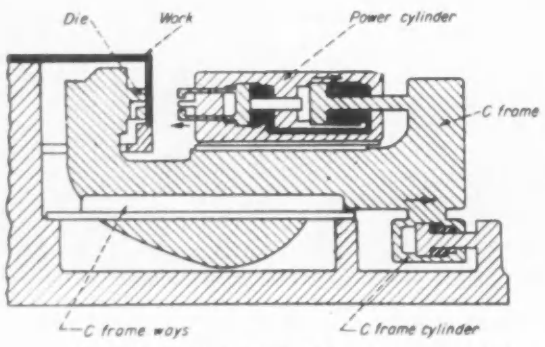


FOUR FLEXURE MEMBERS (two at the table and two at armature coil) provide rigid radial support for the table-armature assembly and bend to permit the axial oscillations. Notice the triangular shape of the main flexure beam. With the large end securely clamped to the field structure and the small end free to move with the table, this tapered design evenly distributes the flexure stresses along the beam length. Notice the removable stainless steel inserts by which equipment can be mounted to the table for testing purposes.

Sliding C-Frame Balances Piercing Force

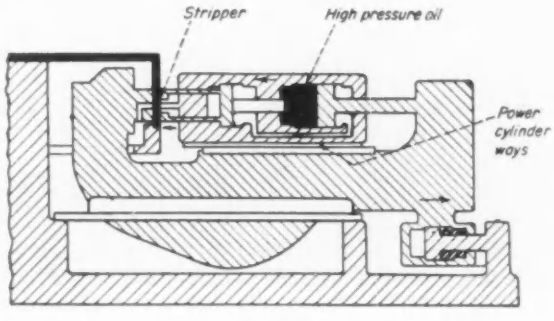


HYDRAULIC PIERCING MACHINE, set up for piercing eliptical holes in a jet engine exhaust ring, has a capacity of 56 tons at 10,000 psi oil pressure to the punch. Its automatic cyclic rate of operation is 30 holes per minute. The machines are equipped with a 5-1 booster and are available with either 5,000 psi or 10,000 psi punch pressure.



OPERATING CYCLE OF PUNCHING PROCESS

Step No. 1—Primary oil is directed to the C frame cylinder which positions the die behind the work piece.



Step No. 2—The power cylinder advances the punch head and positions the stripper opposite the die.

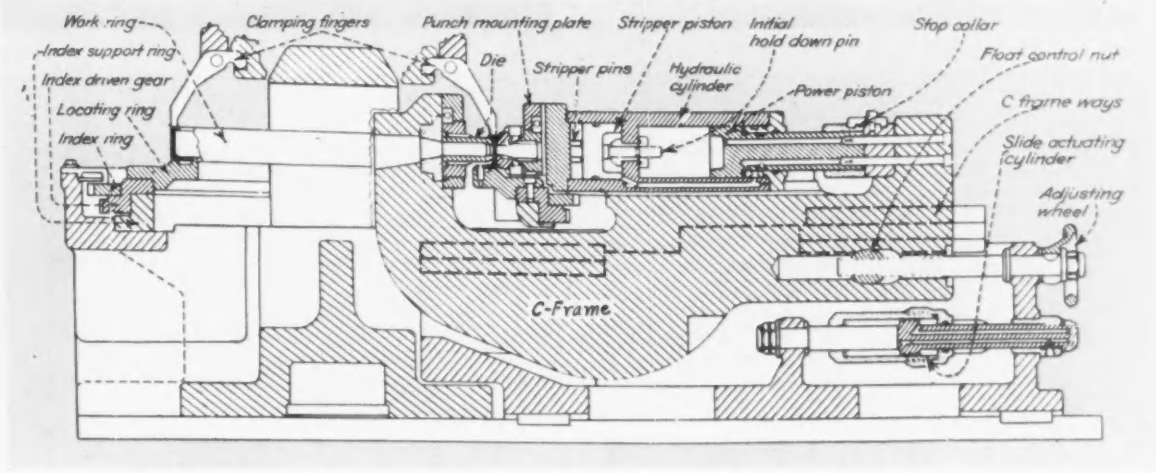
To prevent distortion of a work-piece being processed in this hydraulic piercing machine, the force exerted by the punch head is supplemented by an equal amount of backup force at the die. That section of the work being pierced is merely clamped between the die and punch head during the punching operation, with no lateral movement permitted.

The basic element for this action is a sliding C frame on which the die and punch head are mounted and positioned on opposite sides of the work. This C frame rides in V ways on the machine base and carries the die, fixed at the head of the frame, to and from the work. It is moved by a hydraulic cylinder and stopped at both open and closed positions by an adjustable float control screw anchored to the main base. The punch head assembly slides in V ways on the throat of the C frame and is advanced to the die by an internal hydraulic cylinder.

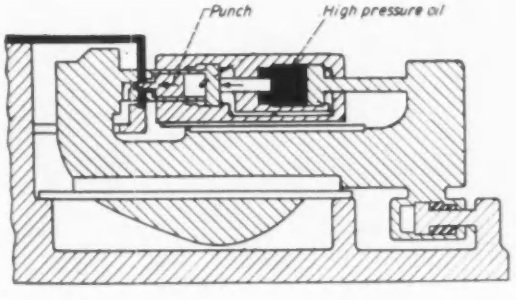
Three hydraulic circuits are used. A pilot circuit of 200 psi actuates the sequence controls and drives the indexing rotary work table. The C frame cylinders are provided with a 1,000 psi circuit and a pressure converter supplies 10,000 psi for the actual punching operation.

This converter detects the decrease in pressure drop in the primary circuit when clamping action in the frame is complete. Then it sends the high pressure oil to the punch. When punch pressure is released by a time delay in the electronic control panel, a decompression spool in the control valve of the converter prevents pressure surge returned from the high pressure circuit. This eliminates any shock as the punch breaks through.

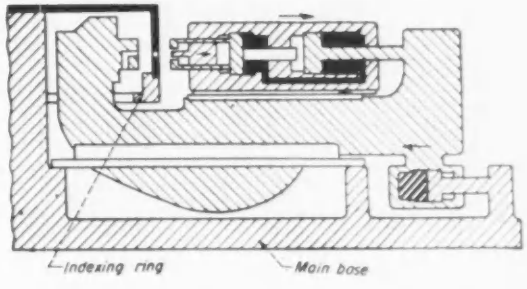
Original development work was done by Mueller Engineering Company, Dearborn, Mich., but Danly Machine Specialties Inc., Chicago, Ill., are making it.



CROSS-SECTION of C frame at closed position shows how oil pressure is ported to the slide actuating cylinders. When punching operation is completed, an electronic time delay relay relieves high punching pressure and primary pressure opens the frame. Dotted lines indicate the double V way on which the C frame rides.

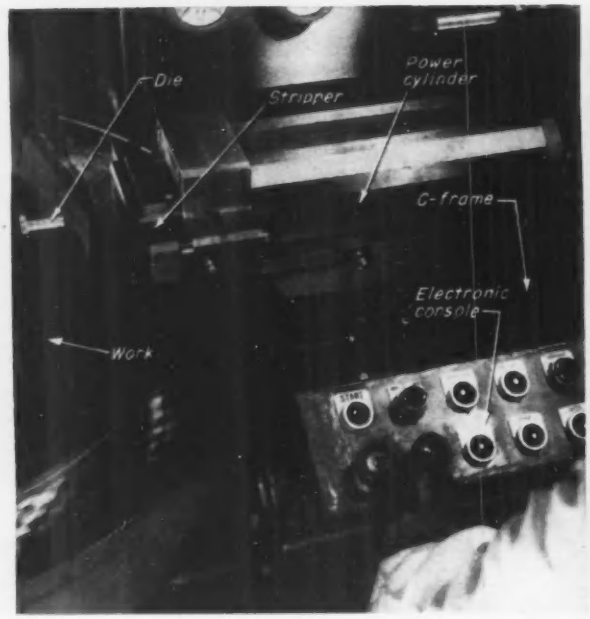


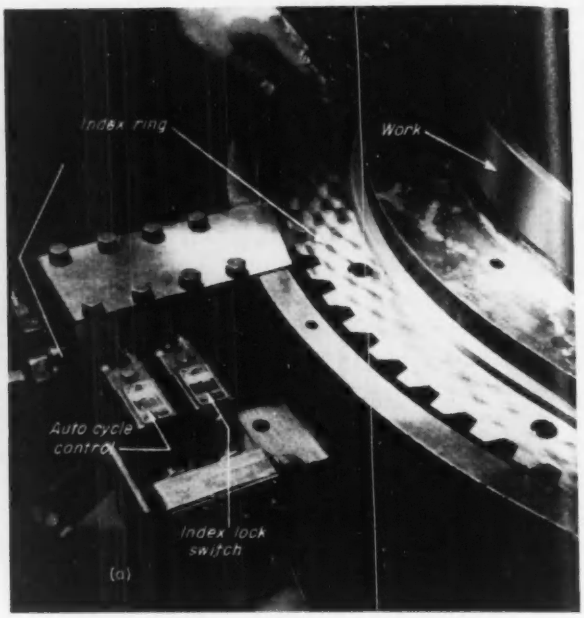
Step No. 3—Hydraulic converter sends high pressure oil to drive the punch through the work.

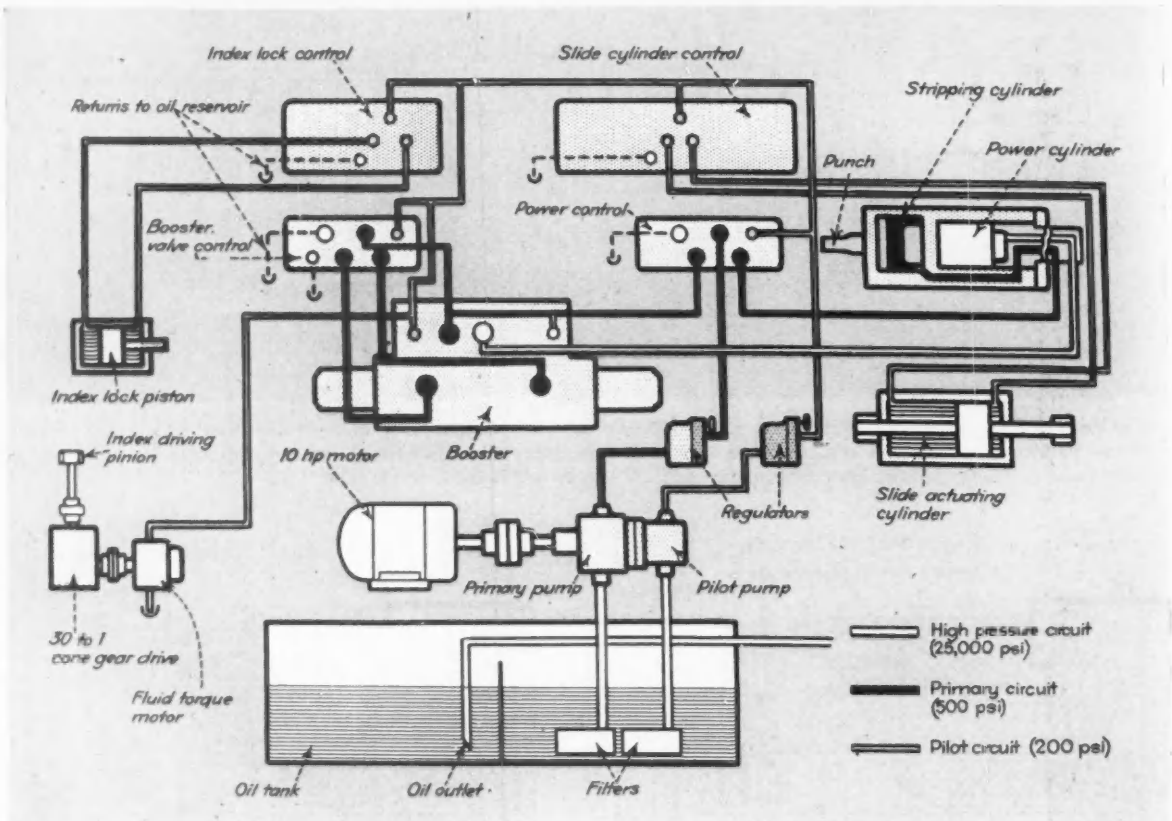


Step No. 4—High pressure oil is relieved. Primary pressure pulls back punch head strippers from the work. Frame moves away and the work is free to index.

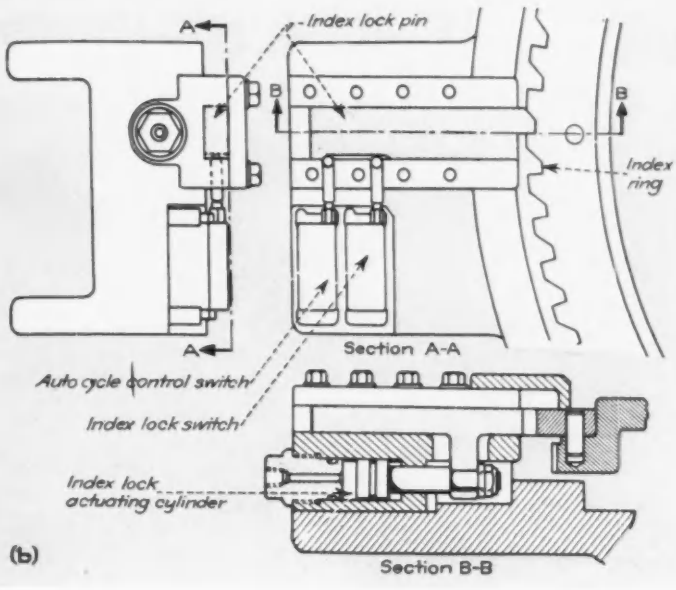
Hydraulic Piercing Machine (continued)





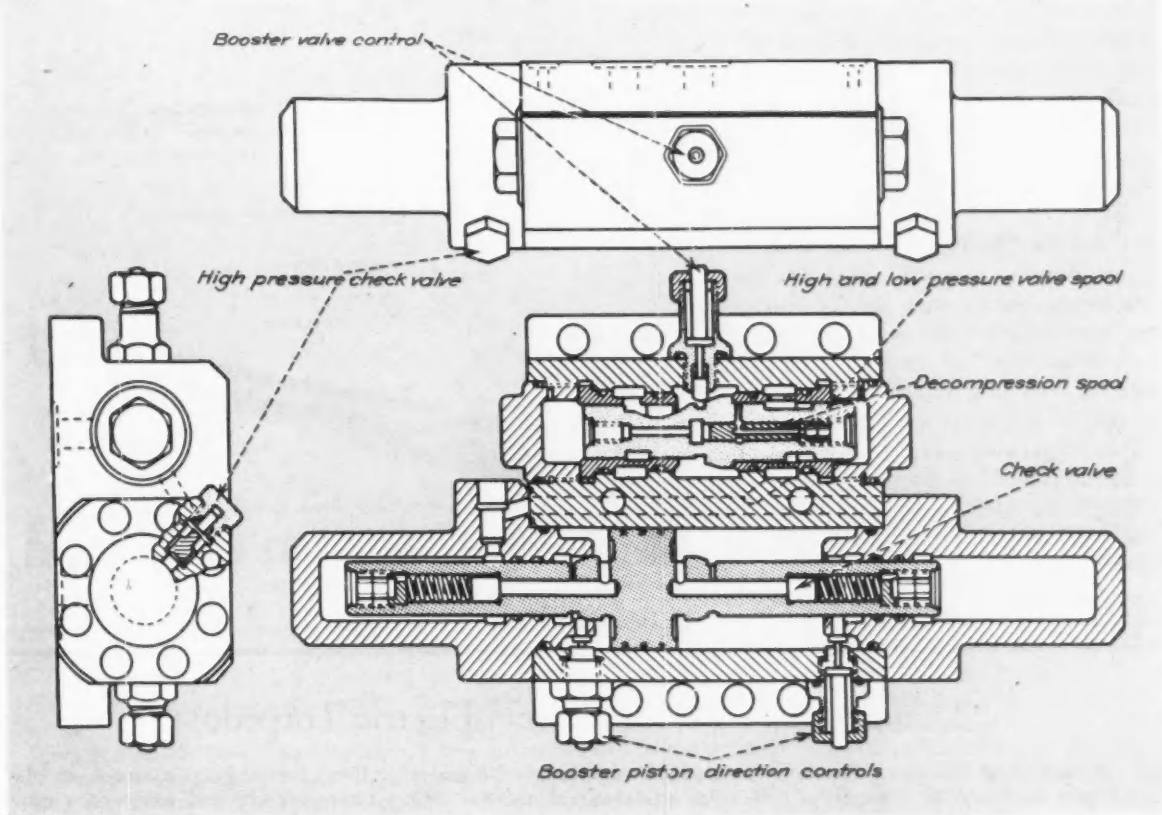


PRIMARY AND PILOT PUMPS are mounted together on a common shaft from a 10 hp electric motor. The electronic timer controls the pilot pressure which actuates the valves of the primary circuit. All high pressure controls are in the hydraulic converter unit. Standard fittings are used throughout the system and all have ample safety factors. Notice that the indexing elements and the C frame positioning cylinder are powered by oil from the pilot circuit. All return oil is directed to a cooling tank (not shown) where it is forced through water cooled tubes before it reaches reservoir. Upper photos show closeups of stripping operation (left) and indexing mechanism (right).



POSITION of the piercing component's (left) before cycle is started. Here, the stripper is extended ready to make initial contact with the work. Selector switches on the electronic control console provide either manual or automatic operation.

INDEX LOCK PIN serves as a positive stop for the index ring during the actual operating cycle. When the lock pin is withdrawn by hydraulic pressure, the index ring starts to rotate, and simultaneously, the oil pressure on the lock pin is reversed and the pin slides into the next slot. A constant torque is kept on the index ring by a fluid motor thus keeping the ring firmly seated against the index lock pin and insuring an exact duplication of the spacing on the index ring.



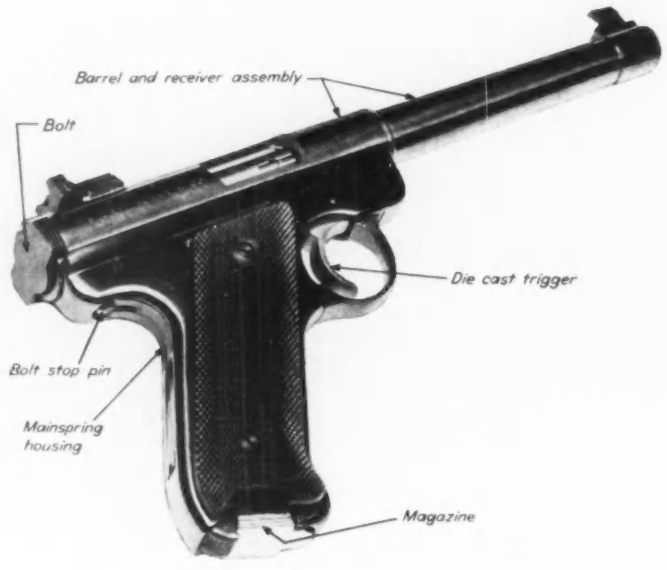
UPPER SECTION of the hydraulic converter unit is a pressure governing element detecting the need for high or low pressure at the punch. The lower portion is the hydraulic intensifier that produces the high pressure necessary for piercing. As the punch and stripper approach the work, minimum pressure is required. When the punch contacts work and increased pressure is needed, the valve spool directs oil to the booster unit and the punching operation takes place at the higher pressure. Time relay actuates the valve that redirects oil to spool to reverse the booster piston action. High pressure bleeds through decompression spool to prevent break-through shock.

Stampings Reduce Cost of .22

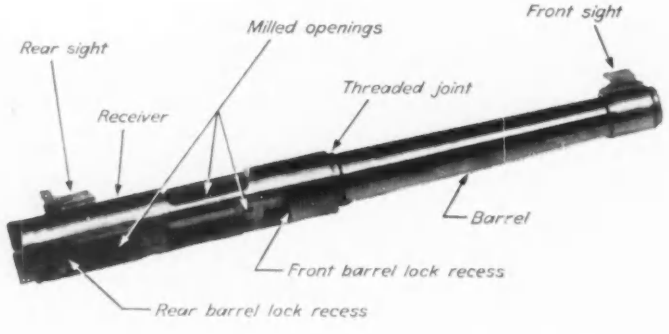
By using stampings for the grip frame, main spring housing, and various smaller parts, and by designing the barrel receiver assembly for relatively simple machining, Sturm, Ruger & Co., Inc., Southport, Conn. has developed a low-cost 22 calibre target pistol that compares favorably in performance and appearance with more conventional designs. The grip housing is a pair of heavy stampings mated and welded together to form the magazine holder and housing for the hammer actuating elements. The receiver is a length of seamless steel tubing on which all critical machining is done after it is screwed securely to the finished barrel, thus minimizing the problem of alignment of the barrel and receiver during assembly. The stampings and tubular receiver serve in place of the forged and milled receivers and sliding breech blocks in common use.

The main spring housing is a laminated assembly of three stampings, copper brazed together. This assembly serves the three fold-purpose of containing the main firing spring with plunger, the bolt stop pin, and the housing latch. Both ends of the main spring are actively used. The top end powers the hammer and the bottom end carries the ball for the housing latch cam detent. The bolt stop pin locks the receiver onto grip frame and makes an anchor for the bolt return spring.

The trigger mechanism follows standard action but several of the small parts in it (firing pin, safety latch, sear bar) are stampings of high grade steel instead of conventional machined parts.



TARGET MODEL above is 10⅞ in. long and weighs 42 oz. Its magazine carries 9-.22 calibre long rifle cartridges. Screws hold hard rubber grip to stamped steel grip frame. These are the only screws in the pistol.

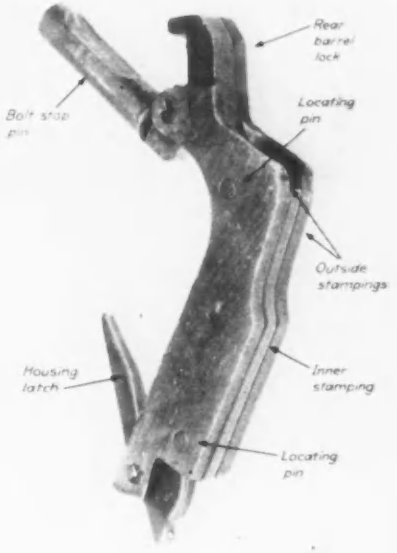


Double Drive Motor Powers Electric Torpedo

IN THE PROCESS of developing a better torpedo for the Navy, the engineers of Westinghouse Electric Corporation, Pittsburgh, Pa., came up with an electric motor that turns the contra-rotating torpedo propellers with equal power in opposite directions without the need of a reversing gear transmission. Specific details and performance of the unit are classified, but in general it takes advantage of the fact that motor operation and rating are dependent on the relative motion between the rotor and the stator and not just on the absolute rotation of the rotor alone.

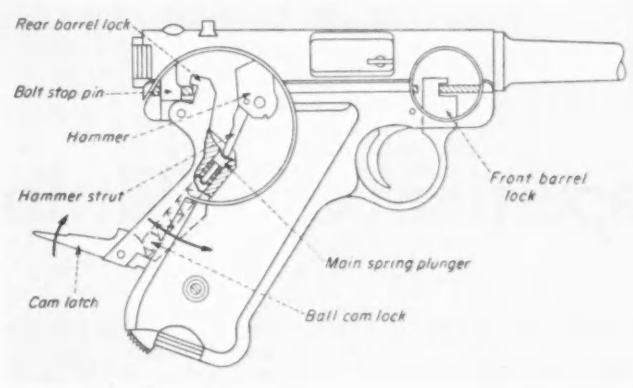
In this design, both the field structure and the rotor are free to turn. They are bearing mounted in the motor housing and rotate on a common axis with power being delivered through coaxial shafts. When the motor is energized the induced magnetic field causes equal and opposite reactions in both elements with both elements free to turn. The resultant rotation is directed to the contra-ro-

Caliber Target Pistol



HEAVY FOLD in the left side stamping stiffens the assembly and makes a channel for the cartridge magazine. Rivets that hold the trigger guard in the assembly are spun set and polished. When finished, weld is invisible.

TWO OUTSIDE STAMPINGS of the laminated main spring housing are identical. Center holds the housing latch and bolt.



THE BARREL-RECEIVER ASSEMBLY is held to the grip frame by an extension on the trigger guard, the main spring housing and the bolt stop pin. With main spring housing in place (arrows show direction of movement) housing latch will swing into its recess and lock assembly together.

BARREL and tubular receiver are permanently assembled by 20 pitch screw threads prior to machining the receiver. Since the front and rear sights are carried on the unit assembly there is no relative motion between them to spoil their alignment during firing.

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tating propellers through the coaxial shafts.

When both the propellers attached to the contra-rotating shafts are submerged, resistance to their turning is equal and therefore power and rpm delivered are equal.

This double-delivery motor added greatly in the development of the electric torpedo. Through its use, a weapon was developed that had many advantages over the older compressed-gas driven models. The new torpedo leaves no bubble trail in the water to warn of its coming. By eliminating the need for the reversing gears, the power package can be made lighter, smaller and makes less noise; thus making detection by sonar more difficult. Because it strikes without warning, the torpedo has a demoralizing effect on enemy personnel.

As a result of the continued effort to reduce weight and increase strength, the shell of the torpedo is made of welded aluminum alloy. Previous shells were made of cast aluminum or welded steel plates.

Although the new weapon is much smaller and lighter than previous designs, it has greater speed, longer range and can operate at greater depths than gas-driven models.

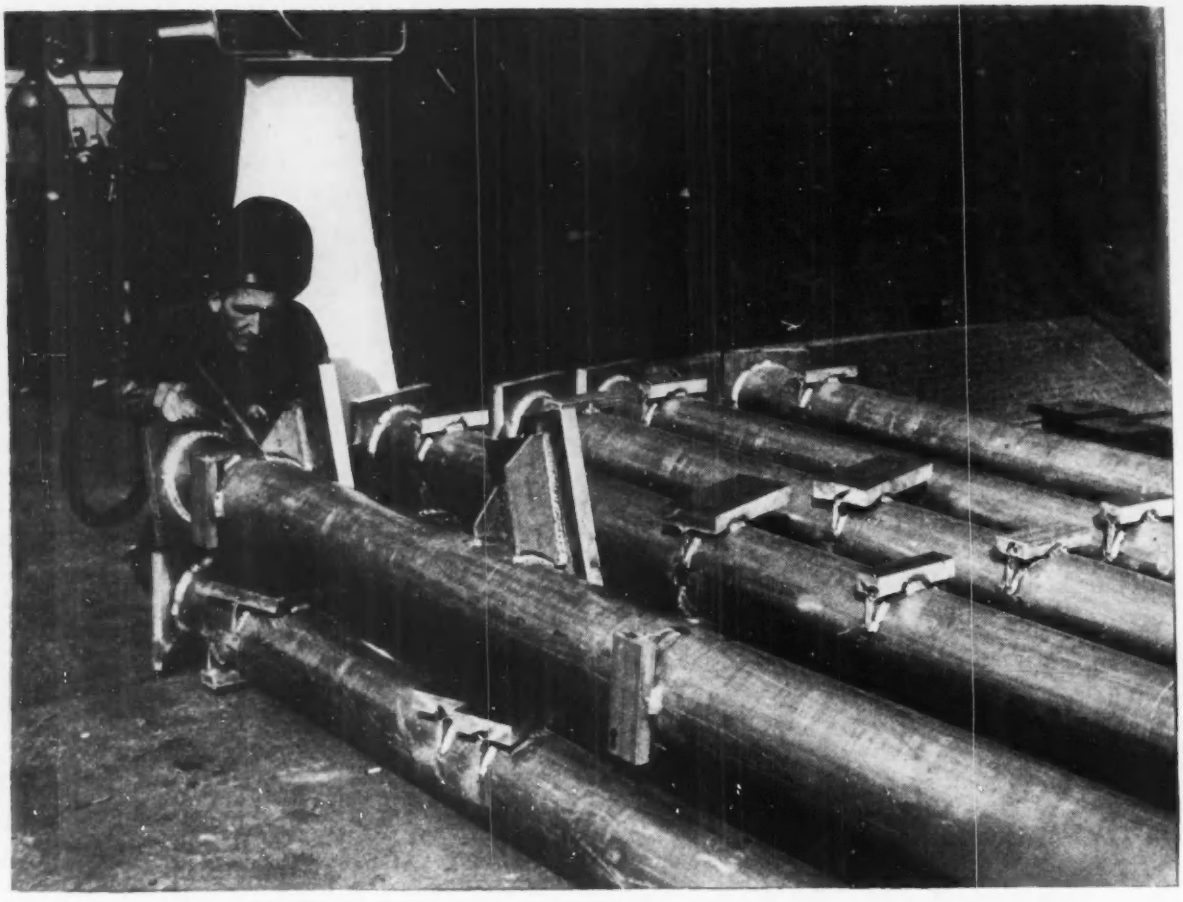


Fig. 1—Center wing main blanket fixture made of Aircomatic welded 61ST aluminum tubes and pads. After the welding operation, all the pads are machined to a close tolerance with little distortion or warpage.

Strength Properties of Welds in

Tensile strength of butt joints and shear strength of lap joints in aluminum alloy sheet as obtained with the inert gas welding process where the filler wire is used for the electrode.

LOUIS BARRETT
Welding Engineer
The Glenn L. Martin Company

ALUMINUM TEST SPECIMENS welded by a recently developed process show a weld quality comparable to that obtained by inert gas shielded arc welding with tungsten electrodes. The lack of warpage and distortion encountered with the new process makes it acceptable for welding on tools, jigs, and fixtures, and ground handling and electronic equipment. The Glenn L. Martin Company has found that, in general, as compared with other established welding processes the new process saves from 60 to 75 percent of welding time.

The new process, known as Aircomatic, differs essentially from the shielded arc process in that the filler metal replaces the tungsten electrode. The consumable electrode filler wire is continuously fed through a gun-type torch along with the flow of inert gas. The ease with which the gun can be handled in a confined working space is an advantage.

With the high current densities employed and the deep penetration achieved, manual welding speeds ranging from 20 to 24 in. per minute are practical.

An investigation of the soundness and strength of welds in 61S-T6 aluminum alloy sheet welded by the new process was prompted by a proposed application that would utilize to advantage the speed and efficiency of the new process.

In preparing shear and tensile specimens for the investigation, the power

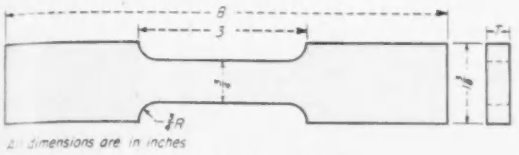
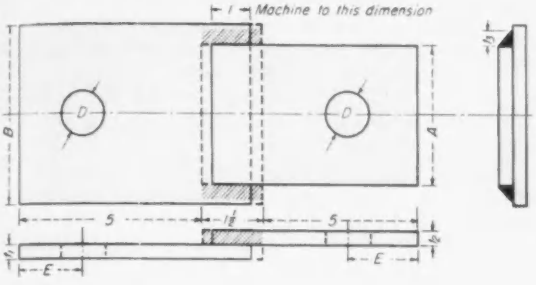


Fig. 2—Dimensions of tensile test specimens made of 61S aluminum alloy sheet.



$t_1 = t_2 = t_3$	A	B	D	E
$\frac{1}{8}$	2	3	$\frac{5}{8}$	$1\frac{1}{4}$
$\frac{3}{8}$	4	5	$1\frac{1}{4}$	$2\frac{1}{2}$

All dimensions are in inches

Fig. 3—Dimensions of shear test specimens made of 61S aluminum alloy. Dash lines indicate material removed in machining.

Table I—Welding Schedule for Test Specimens

Specimen	Electrode Speed, in per min.	Amp.	Inert gas flow, cu ft/hour	
			Helium	Argon
1/8 in. tensile	144	150	20	17
1/8 in. shear	126	145	0	15
3/8 in. tensile	180	180	30	21
3/8 in. shear	180	180	30	21

Table II—Average Values of Tensile Tests of Welds in 61S-T6 Sheet

H.T. = Solution heat-treated and aged after welding
A.W. = As welded; no heat-treatment after welding
A. = Electrode filler wire, inert gas welding process
B. = Tungsten, gas shielded arc welding process

Condition of Specimen	Weld. Proc.	Average Yield Stress, psi	Average Ultimate Stress, psi	Average Elong. in 2 in., percent	Failure
1/8 in. Sheet					
Bead on; H.T.	A	46,160	50,000	9.6	Parent metal
Bead on; H.T.	B		46,300	9	
Bead on; A.W.	A	22,020	31,380	5.5	Heat affected zone
Bead on; A.W.	B		28,900	4	
Bead off; H.T.	A	45,640	46,870	2.4	Weld
Bead off; H.T.	B	41,600	46,300	9	
Bead off; A.W.	A	20,410	31,810	6.7	(See Comment A)
Bead off; A.W.	B	19,000	29,300	5.5	
3/8 in. Sheet					
Bead on; H.T.	A	41,040	47,150	8	Edge of Weld
Bead on; H.T.	B		41,800	9	
Bead on; A.W.	A	17,740	26,620	12	(See Comment B)
Bead on; A.W.	B		27,200	11	
Bead off; H.T.	A	39,520	43,600	3	Weld
Bead off; H.T.	B	33,000	41,000	17	
Bead off; A.W.	A	16,740	27,520	11	(See Comment C)
Bead off; A.W.	B	16,300	28,200	9	

Comment A: Of 12 specimens tested, 11 failed in the heat affected zone, 1 failed in the weld.

Comment B: Of 5 specimens tested, 3 failed in the heat affected zone, 1 failed in the weld where penetration was incomplete, and 1 failed in the weld where a small inclusion was present. Elongation values for the two specimens that failed in the weld are not included in the average value.

Comment C: Of 10 specimens tested; 9 failed in the heat affected zone; 1 failed in the weld where an oxide inclusion was present, elongation value for this specimen is not included in the average value.

61S-T6 Aluminum Alloy Sheet

source for the gun was a 400 ampere, d-c, reverse polarity generator. For all welds, the electrode filler was 1/16 in. dia. 43S aluminum alloy. The automatic feed for the filler wire was controlled by a selector switch on the gun. All specimens were degreased and wire brushed prior to welding.

Tensile Specimens and Tests

Tensile specimens were made in $\frac{1}{8}$ in. and $\frac{3}{8}$ in. thick 61S-T6 sheet by butt welding two 4 in. by 12 in. sheets together along the 12 in. length in accordance with the welding schedule given in Table I. The sheets of $\frac{1}{8}$ in. thickness were butted together with no edge preparation, tack welded at each end and then welded in a single pass. A back-up plate containing a groove was used to prevent burning through during welding. Radiographs showed the welds to be free of blowholes and porosity.

The sheets of $\frac{3}{8}$ in. thickness were butt welded together using a full 45 deg bevel from one side for edge preparation. No back-up plate was used. The beveled trough was filled in three passes. Radiographs showed a little porosity distributed throughout the welds. Although not desirable, the porosity was not considered excessive.

Each welded panel was cut into strips $1\frac{1}{2}$ in. wide by 8 in. long and the end strips discarded. The remaining six strips were machined into tensile specimens $1\frac{3}{8}$ in. wide as shown in Fig. 2. Sufficient specimens were prepared to investigate the strength of welds under four conditions:

1. Bead on; heat-treated.
2. Bead on; as welded.
3. Bead off; heat-treated.
4. Bead off; as welded.

Average values of the results of the tensile tests are given in Table II and designated "Welding Process A" for these specimens.

Shear Specimens and Tests

Shear specimens of $\frac{1}{8}$ in. and $\frac{3}{8}$ in. sheets were welded and machined in accordance with the specifications shown in Fig. 3 and the welding schedule in Table I. A copper backup plate was used on the $\frac{1}{8}$ in. specimens

to keep the heat down and to prevent underbead cracking. Shear tests were run on specimens in both the as welded and heat-treated conditions. The shear stress was calculated in the usual manner by using the thickness of the sheet and not the throat of the fillet. In Table III, under the welding process designated A, are given the average shear stress obtained for the $\frac{1}{8}$ in. and $\frac{3}{8}$ in. specimens.

To compare the strength of welds produced by the electrode filler wire inert gas welding process with that of welds produced by the tungsten gas shielded arc welding process, some average tensile and shear strength properties of shielded arc welds, taken from previous test reports, are given in Tables II and III under the respective welding process designation.

The large difference in elongation in the heat-treated bead off specimens is explained by the fact that the shielded arc welds failed in the parent metal and the Aircomatic welds failed in the weld metal.

Temperature measurements were obtained at the side of the weld bead immediately after the Aircomatic welding was completed. Single pass welding caused the temperature of the sheet to rise approximately 200 deg F. In a three-pass weld, the second pass caused a maximum rise of 325 deg F, while the third pass caused a maximum rise of 450 deg F at the weld.

The high welding speeds that characterize the Aircomatic welding process tend to narrow the width of the heat affected zone, therefore, a greater portion of the parent metal retains its original strength.

The high current densities required to produce rapid welding are an additional advantage in that a greater depth of penetration can be obtained, particularly where thick gage material is being welded. The high current densities, however, are not readily tamed down to prevent burning through on thin gage metal. From work done to date, it seems that any material less than $\frac{1}{8}$ in. thick will be difficult to weld by the electrode filler wire inert gas welding process. In brief, the advantages of this welding process are its speed, efficiency, good depth of penetration, and accessibility to confined areas.

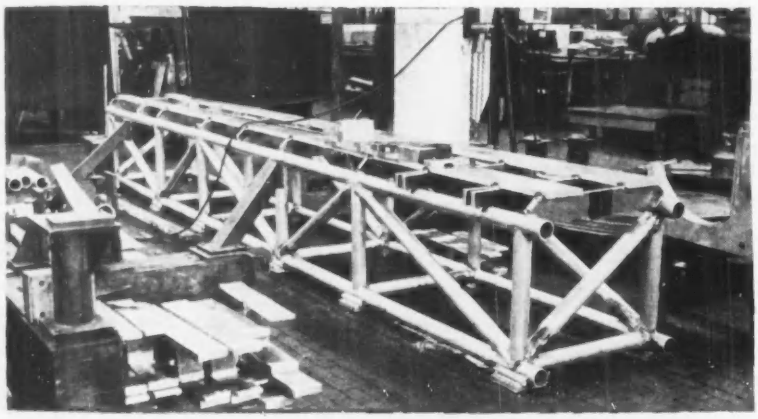


Fig. 4—Wing leading edge bonding fixture weld fabricated of 61S-T6 aluminum alloy tubing 3 in. dia by $\frac{1}{4}$ in. wall thickness.

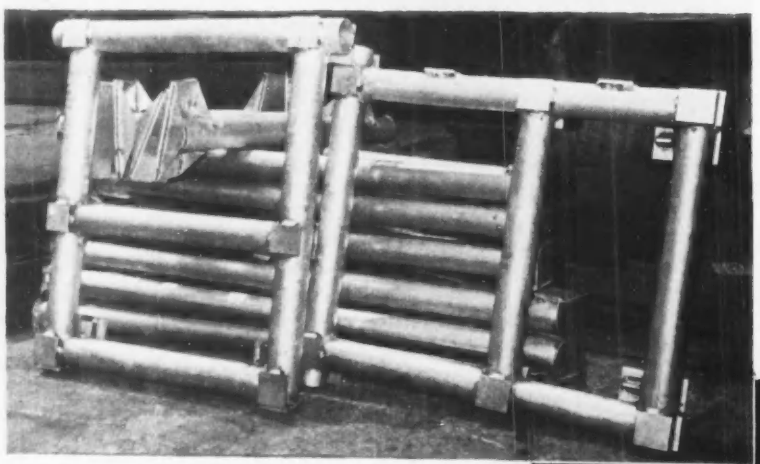


Fig. 5—Hydro-flap frames weld fabricated of 61S-T6 alloy pipe 6 in. dia by $\frac{1}{4}$ in. wall thickness. Pads $\frac{1}{4}$ in. thick are welded to pipe. Accessibility at joints promoted rapid welding.

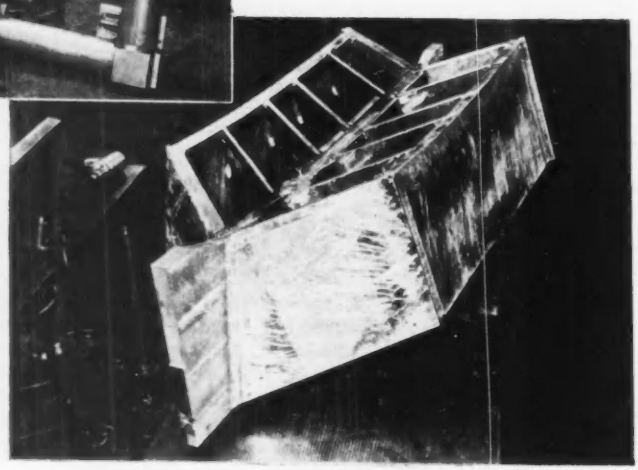


Fig. 6—Stabilizer bonding fixture fabricated of 61S-T6 aluminum alloy plates with Aircomatic welding process. Frame plates are $1\frac{1}{4}$ in. thick; inside spacers are $\frac{1}{4}$ in. thick. Warpage was so slight that straightening was not required.

Table III—Average Values of Shear Tests of Welds in 61S-T6 Sheet

H.T. = Solution heat-treated and aged after welding
A.W. = As welded; no heat-treatment after welding
A. = Electrode filler wire, inert gas welding process
B. = Tungsten, gas shielded arc welded process

Condition of Specimen	Average Shear Stress, psi	
	Weld. Process A	Weld. Process B
1/8 in. Sheet, H.T.	23,600	18,360
1/8 in. Sheet, A.W.	14,930	12,260
3/8 in. Sheet, H.T.	13,180	15,730
3/8 in. Sheet, A.W.	9,820	10,090

Isolating the Noise and Vibration of Rotating Machines

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For optimum isolation, all three transmissibilities—vertical, horizontal and moment—must be reduced to an optimum condition. This can now be done analytically without the expensive and time-consuming tests normally required. Three equations are generally required. These are given herein with a brief treatment of how they can be developed.

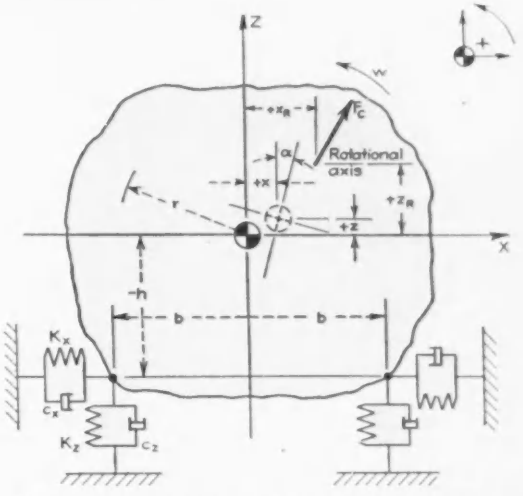


Fig. 1—Schematic diagram of a rotating machine with symmetrically located base mounts. For optimum isolation, the mounts must reduce all three modes of vibration caused by F_c, which is the unbalanced force of the rotor.

MANY ROTATING MACHINES are installed in places where the vibration and noise transmitted to adjacent structures must be held to an absolute minimum. Such installations frequently use resilient-type mounts to isolate the oscillatory forces and torques. But the methods used to select these mounts are often crude and amount to little more than trial and error testing. A common practice is to select a mount tentatively on the basis of vertical transmissibility. Expensive, time-consuming tests under operating conditions are used to determine the effectiveness of these mounts for isolating the other vibration modes.

To eliminate this trial and error technique, an analytical approach was developed that takes into consideration horizontal and moment transmissibility as well as vertical transmissibility. Its application to rotating naval machinery has eliminated costly noise tests. As presented herein, the results are applicable to rotating machines on symmetrically located base mounts. Two cases of impressed vibration are considered. The first deals with an impressed centrifugal force such as that caused by an unbalanced rotor; the second considers a vibratory torque resulting from a torque reaction or an oscillating magnetic field.

Centrifugal Force Transmissibilities

The type of installation for which this analysis is valid is represented schematically in Fig. 1. The values of the transmissibilities, or ratios of transmitted to impressed forces, are based on the following characteristics of the mounts and the machine:

K_x, K_z = total horizontal and vertical dynamic mount stiffnesses
c_x, c_z = total horizontal and vertical damping coefficients
m = mass of machine
r = radius of gyration of machine about the center of gravity in the plane of the centrifugal force
b, h = horizontal and vertical distances from the mounts to the center of gravity
x_c, z_c = horizontal and vertical distances from the shaft to the center of gravity
x, z, α = horizontal, vertical, and rotational displacement of the center of gravity. Single or double dots over the letter indicates velocity or acceleration, respectively
ω = rotational speed, radians per unit time

A summation of the forces and torques about the center of gravity yields:

$$\Sigma F_z = F_c \sin \omega t - K_z z - c_z \dot{z} = m \ddot{z} \quad (1)$$

$$\Sigma F_x = F_c \cos \omega t - K_x (x - h\alpha) - c_x (\dot{x} - h\dot{\alpha}) = m\ddot{x} \quad (2)$$

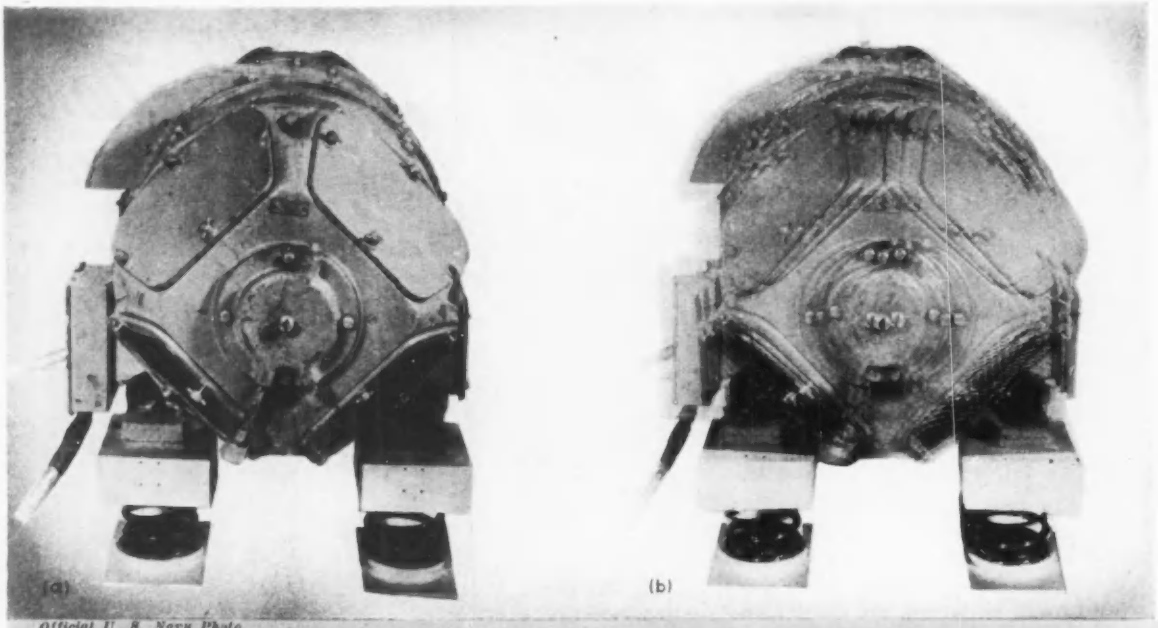
$$\Sigma T_y = F_c (x_c \sin \omega t - z_c \cos \omega t) + K_x h (x - h\alpha) + c_x h (\dot{x} - h\dot{\alpha}) - K_z b^2 \alpha - c_z b^2 \dot{\alpha} = m r^2 \ddot{\alpha}$$

Eq. (1) is used to derive two equations, the vertical natural frequency and the vertical force transmission, both of which are well known. The vertical undamped natural frequency is given by the following:

$$\omega_z = \sqrt{\frac{K_z}{m}} \quad (4)$$

If the effects of damping are included, the transmissibility for vertical

* Opinions expressed herein are those of the author's and do not necessarily reflect the attitude of the Navy Department or the Naval Establishment at large.



Official U. S. Navy Photo

Fig. 2 (Above)—Motor-generator set under test for isolation of vibration and noise. Springs were selected on the basis of only vertical natural frequency. Result (b) shows that although vertical transmissibility is satisfactory, the normal operating speed is in resonance with the rocking mode lower natural frequency.

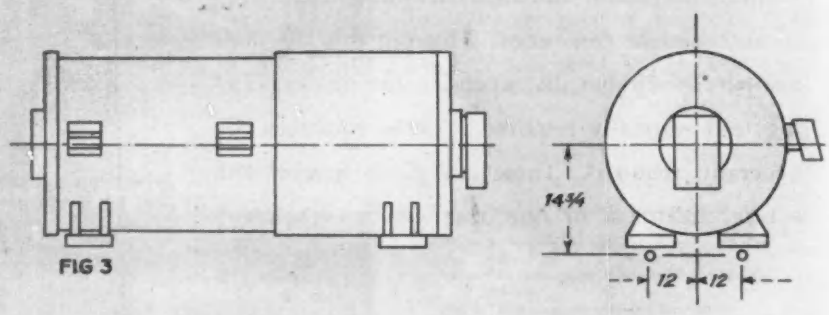


FIG 3

vibrations is given by:

$$T_z = \frac{F_{zo}}{F_c} = \sqrt{\frac{1 + [2\,(c_z/c_{cz})\,(\omega/\omega_z)]^2}{\left[1 - \left(\frac{\omega}{\omega_z}\right)^2\right]^2 + \left[2\,\frac{c_z}{c_{cz}}\,\frac{\omega}{\omega_z}\right]^2}} \quad (5)$$

where F_c is the impressed force, F_{zo} is the vibrating force transmitted vertically through the mounts, and $c_{cz} = 2\sqrt{K\,m}$ which is the vertical critical damping coefficient.

Two other transmissibilities are required for a complete analysis. They are the results of rocking vibrations of the machine. This rocking consists of two components, horizontal translation and rotation, but since it occurs as one vibration, it is called a coupled mode. The horizontal forces on the mounts are used to derive horizontal transmissibility, while the rocking forces vertically on the mounts determine moment transmissibility. Eqs. (2) and (3) are solved simultaneously to obtain these values, which can be expressed as follows:

The horizontal transmissibility is

$$T_x = \frac{F_{xo}}{F_c} = \sqrt{\frac{\left[A^2_x - 2\,\frac{h}{r}\,A_x\,A_\alpha \cos(\psi - \phi) + \left(\frac{h}{r}\,A_\alpha\right)^2\right]\cdot \sqrt{1 + \frac{[2(c_x/c_{cx})\,(\omega/\omega_z)]^2}{K_x/K_z}}}{}} \quad (6)$$

The moment transmissibility is

$$T_m = \frac{M_{ao}}{F_c\sqrt{(h - z_r)^2 + x^2_r}} = \frac{A_\alpha\,(b/r)^2}{K_x/K_z}\sqrt{\frac{1 + [2\,c_x/c_{cx} \cdot \omega/\omega_z]^2}{(h/r - z/r)^2 + (x_r/r)^2}} \quad (7)$$

where F_{xo} is the oscillating force transmitted horizontally through the mounts, M_{ao} is the vibrating transmitted moment, and $c_{cx} = 2\sqrt{K_x m}$, the horizonal critical dampening.

As used in Eqs (6) and (7)

$$A_x = \frac{K_x}{K_z}\sqrt{\frac{H^2 + I^2}{D^2 + E^2}} \quad (8)$$

$$A_\alpha = \frac{K_x}{K_z}\sqrt{\frac{J^2 + K^2}{D^2 + E^2}} \quad (8a)$$

and the phase angles

$$\tan\psi = \frac{(D\,I + E\,H)}{(D\,H - E\,I)} \quad (8b)$$

$$\tan\phi = \frac{(D\,K + E\,J)}{(D\,J - E\,K)} \quad (8c)$$

To determine the values, use:

$$D = \left(\frac{\omega}{\omega_z}\right)^4 - \left[\frac{K_x}{K_z} + \frac{K_x}{K_z}\left(\frac{h}{r}\right)^2 + \left(\frac{b}{r}\right)^2 + 4\sqrt{\frac{K_x}{K_z}}\left(\frac{b}{r}\right)^2 \left(\frac{c_x}{c_{cx}}\right)\left(\frac{c_z}{c_{cz}}\right)\right]\cdot \left[\frac{\omega}{\omega_z}\right]^2 + \left(\frac{K_x}{K_z}\left(\frac{b}{r}\right)^2\right] \quad (9)$$

$$E = 2\frac{\omega_z}{\omega^2}\left\{\left[\frac{\omega}{\omega_z}\right]^2\left[\left(\sqrt{\frac{K_x}{K_z}}\right)\left(\frac{h}{r}\right)^2\frac{c_x}{c_{cz}} + \left(\frac{b}{r}\right)^2\frac{c_x}{c_{cz}} + \sqrt{\frac{K_x}{K_z}\frac{c_x}{c_{cz}}}\right] - \left[\frac{h}{r}\right]\left[\sqrt{\frac{K_x}{K_z}}\frac{c_x}{c_{cz}} + \frac{K_x}{K_z}\frac{c_z}{c_{cz}}\right]\right\} \quad (9a)$$

$$H = \frac{K_x}{K_z}\frac{h}{r}\frac{x_r}{r} - \left[2\frac{\omega}{\omega_z}\right]\left[\sqrt{\frac{K_x}{K_z}}\frac{h}{r}\left(\frac{h}{r} - \frac{z_r}{r}\right)\left(\frac{c_x}{c_{cz}} + \right)\left(\frac{h}{r}\right)^2\frac{c_z}{c_{cz}}\right] \quad (9b)$$

$$I = \frac{K_x}{K_z}\frac{h}{r}\left(\frac{h}{r} - \frac{z_r}{r}\right) + \left(\frac{h}{r}\right)^2 - \left(\frac{\omega}{\omega_z}\right)^2 + \left[2\sqrt{\frac{K_x}{K_z}}\frac{h}{r}\frac{x_r}{r}\frac{\omega}{\omega_z}\frac{c_x}{c_{cz}}\right] \quad (9c)$$

$$J = \frac{x_r}{r}\left[\frac{K_x}{K_z} - \left(\frac{\omega}{\omega_z}\right)^2\right] - 2\sqrt{\frac{K_x}{K_z}}\left(\frac{h}{r} - \frac{z_r}{r}\right)\frac{\omega}{\omega_z}\frac{c_x}{c_{cz}} \quad (9d)$$

$$K = \frac{K_x}{K_z}\left(\frac{h}{r} - \frac{z_r}{r}\right) + \frac{z_r}{r}\left(\frac{\omega}{\omega_z}\right)^2 + 2\sqrt{\frac{K_x}{K_z}}\frac{x_r}{r}\frac{\omega}{\omega_z}\frac{c_x}{c_{cz}} \quad (9e)$$

The values of the phase angles can be found from their tangents in Eqs (8b) and (8c), by using Table I below.

EXAMPLE:

The motor-generator set in Fig. 3 has the following dimensions:

$h = -14\ 3/4$ in.
$b = 12.0$ in.
$r = 9.1$ in.
$x_r = 0$
$z_r = 0$
$W = 3750$ lb

Table I—Valves of Phase Angles

$(DI + EH)$	$(DH - EI)$	ψ, deg
+	+	0 to 90
+	−	90 to 180
−	−	180 to 270
−	+	270 to 360

$(DK + EJ)$	$(DJ - EK)$	ϕ, deg
+	+	0 to 90
+	−	90 to 180
−	−	180 to 270
−	+	270 to 360

Mounts are chosen having

$K_x = 81{,}200$ lb/in.
$K_z = 70{,}000$ lb/in.

The mass and the vertical natural frequency are

$$m = \frac{3750\text{ lb}}{386\text{ in./sec}^2} = 9.72\ \frac{\text{lb sec}^2}{\text{in.}}$$

$$\omega_z = \frac{70{,}000}{9.72} = 84.8\text{ radians/sec}$$

Thus

$$\frac{K_x}{K_z} = 1.16$$

$$\frac{b}{r} = 1.32$$

$$\frac{h}{r} = 1.62$$

To help select the proper mounts, Eqs. (5), (6) and (7) are plotted in Fig. 4 for the dimensions above. To facilitate the calculations, damping is neglected.

If the motor-generator set runs at 1800 rpm, ω is 188.5 radians per sec. Therefore

$$\frac{\omega}{\omega_z} = 2.22$$

From Fig. 4, the vertical, horizontal and moment transmissibilities are:

$T_z = 0.26$
$T_x = 1.12$
$T_m = 0.63$

Because of the large value of hori-

Fig. 3—Isolation solution for this motor-generator set is given in the example in the text. The resilient mounts are located by the dimensions shown. The three transmissibility equations that represent the basis of this solution are plotted graphically in Fig. 4 which appears at the right.

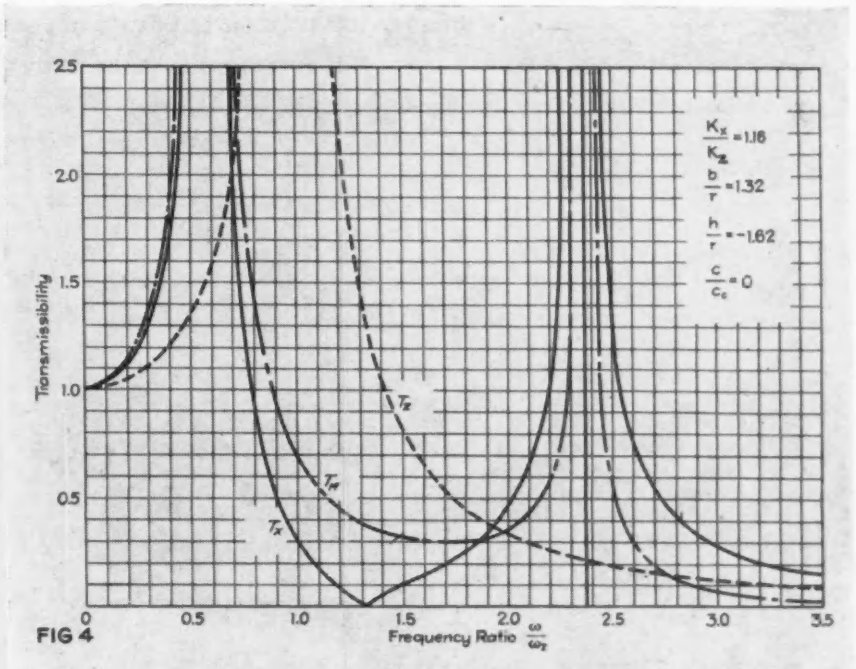


FIG 4

Fig. 4—The advantages of choosing a frequency ratio equal to 1.90 for this motor generator set are obvious from the curves. As an alternative, a value of 3.0 or greater could be selected on the basis of good isolation characteristics, but this would probably sacrifice the stability of the installation.

zontal transmissibility, optimum isolation has not been realized. Referring again to the graphs, it is obvious that the horizontal transmissibility can be reduced by increasing the horizontal and vertical mount stiffnesses. For ω/ω_z of 1.90

$T_z = 0.39$
$T_x = 0.34$
$T_m = 0.31$

The vertical transmissibility is increased slightly, but both the horizontal and moment values are so reduced that the total transmission is considerably lower. An alternative would be to use mounts very soft both vertically and horizontally. This would increase the frequency ratio to 3.0 or more and yield small values of all three transmissibilities. However, good stability would probably be sacrificed.

Torque Transmissibilities

Using methods similar to those for predicting the transmitted vibrations from a centrifugal force, three equations can be derived to determine the transmissibilities from an oscillating torque such as that shown in Fig. 5.

Taking the sum of the forces and torques about the center of gravity

$$\Sigma F_z = -K_z z - c_z \dot{z} = m\ddot{z} \qquad (10)$$

$$\Sigma F_x = -K_x (x - h\alpha) - c_x (\dot{x} - h\dot{\alpha}) = m\ddot{x} \qquad (11)$$

$$\Sigma T_y = T_o \sin \Omega t + K_x h (x - h\alpha) + c_x h (\dot{x} - h\dot{\alpha}) - K_z b^2 \alpha - c_z b^2 \dot{\alpha} = m r \ddot{\alpha} \qquad (12)$$

where

T_o = oscillating torque
Ω = frequency of oscillating torque, radians per unit time.

Eq (10) describes a transient vibration which eventually dies out. Thus the vertical torque transmissibility, T_{tz}, equals zero.

The other two transmissibilities can be obtained by solving Eqs (11) and (12) simultaneously. The horizontal value is

$$T_{tx} = \frac{F_{xo}}{T_o/h} = \frac{h}{r} \sqrt{\left[A_x - 2 \frac{h}{r} A_x A_\alpha \cos(\psi - \phi) + \left(\frac{h}{r}\right)^2 A_\alpha^2 \right]} \cdot \sqrt{\frac{1}{1 + \frac{\left(2 \frac{c_x}{c_{cx}} \frac{\Omega}{\omega_z}\right)^2}{K_x/K_z}}} \qquad (14)$$

The moment transmissibility is

$$T_{tm} = \frac{M_{ao}}{T_o} = \frac{(b/r)^2}{K_x/K_z} A_\alpha \sqrt{1 + \left(2 \frac{c_x}{c_{cx}} \frac{\Omega}{\omega_z}\right)^2} \qquad (15)$$

The values of A_x, A_α, ψ, and ϕ in Eqs (14) and (15), are as before. However, certain other modifications must be made. In Eqs (9) and (9a), Ω/ω_z must be substitued into the expression for D and E in place of ω/ω_z. Also H, I, J and K in this case represent the following:

$$H = \left(\frac{K_x}{K_z}\right) \frac{h}{r} \qquad (9b)$$

$$I = 2 \sqrt{\frac{K_x}{K_z}} \left(\frac{h}{r}\right) \left(\frac{\Omega}{\omega_z}\right) \left(\frac{c_x}{c_{cx}}\right) \qquad (9c)$$

$$J = \frac{K_x}{K_z} - \left(\frac{\Omega}{\omega_z}\right)^2 \qquad (9d)$$

$$K = 2 \sqrt{\frac{K_x}{K_z}} \left(\frac{\Omega}{\omega_z}\right) \left(\frac{c_x}{c_{cx}}\right) \qquad (9d)$$

The expressions for the two torque relationships are shown in Fig. 6 corresponding to the machine and mount characteristics in the sample problem.

Conclusion

When using the analytical approach to select mounts for rotating machinery, the effects of the foundation structure supporting the machines should also be considered. In certain installations, the foundation is more affected by disturbances in one direction than another. For example, if a machine base can support vertical vibrations better than horizontal disturbances, horizontal transmissibility should be minimized even at a reasonable sacrifice of vertical isolation. However, for most installations, the most quiet machine operation is obtained when the sum of all the transmissibilities is minimized.

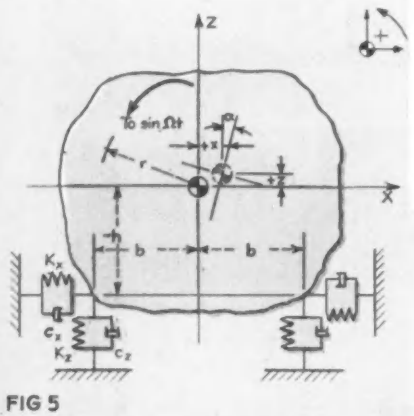


FIG 5

Fig. 5—Schematic diagram for symmetrically located base mounts on a machine subjected to an oscillating torque. Only two transmissibilities must be considered since the vertical mode equals zero.

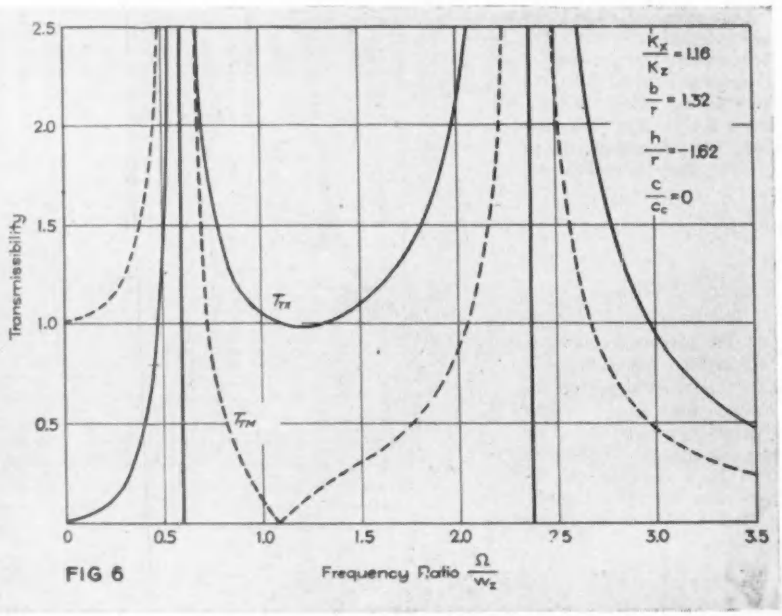
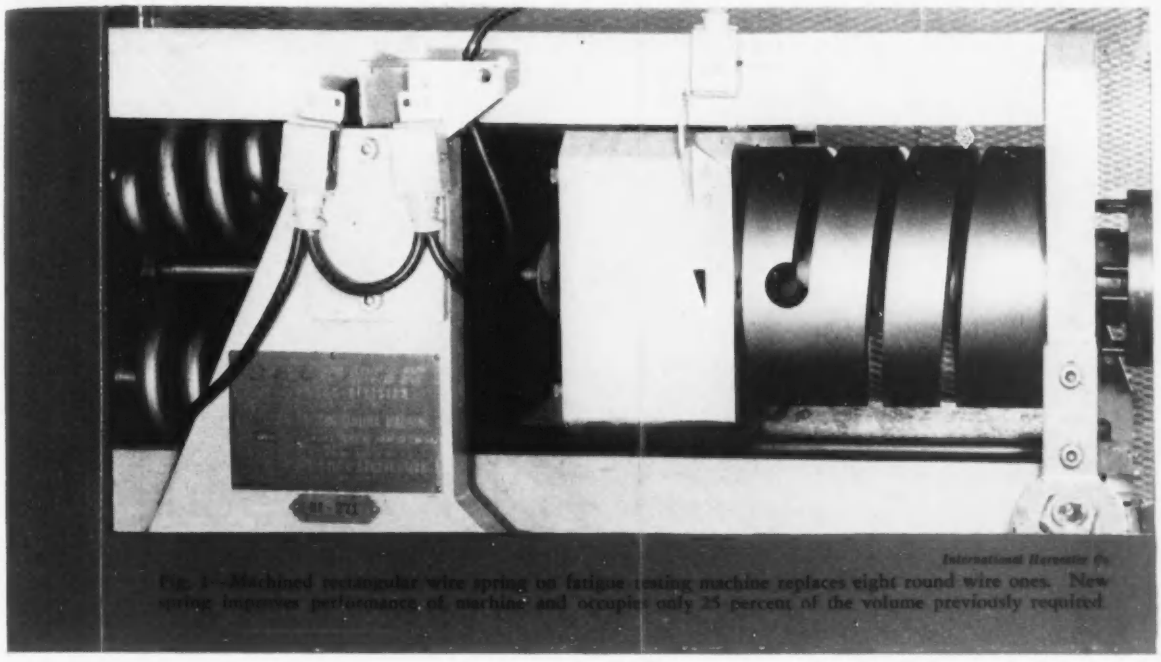


FIG 6

Fig. 6—Plot of the two torque transmissibilities for the same mount and machine characteristics as used in Fig. 3 and the illustrative example in the text.



International Harvester Co.

Fig. 1—Machined rectangular wire spring on fatigue testing machine replaces eight round wire ones. New spring improves performance of machine and occupies only 25 percent of the volume previously required

Streamlining the Selection of Rectangular Wire Helical Springs

Since the basis for most rectangular wire spring applications is their higher capacity per unit volume, this factor has been incorporated into stress and deflection data now available in less convenient forms.

ALEX YORGIADIS

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BECAUSE OF THE ADDITIONAL COST and procurement problems that may be involved, rectangular wire is normally recommended for helical springs only when the diameter or over-all length must be smaller than that necessary with round wire. Thus, a careful evaluation of the advantages of the unconventional wire shape is usually required before rectangular wire is used. Such an analysis can involve a considerable amount of calculation since the performance characteristics obtained with rectangular cross sections are functions of the ratio of the width dimension to the thickness.

The slowest, but probably the most widely used method of obtaining these data, is by using the conventional equations that appear in most design texts. In the past, several charts were developed to eliminate some of the calculations, the most widely used of which are those by Lieseke, VDI, 1933 that also appear in "Mechanical Springs", 1944 by A. M. Wahl. However, the information obtained from these charts still requires considerable processing before any conclusions can be drawn, particularly when space is a prime factor. Therefore, the data from these curves were developed into the more practical and more efficient form shown on the following pages.

Stress Chart

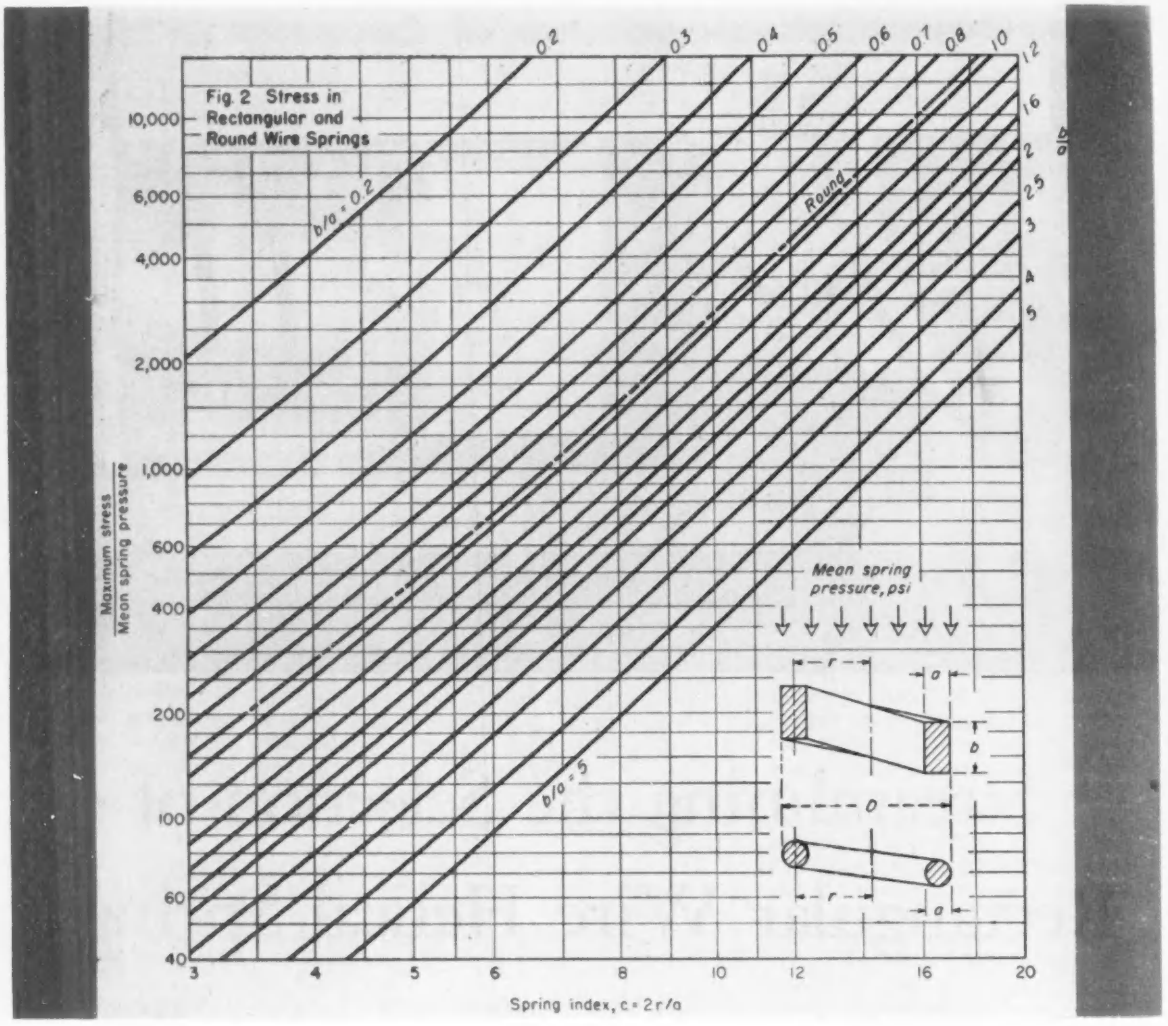
In the original curves, spring capacity is represented by the total applied force. In practice, however, the force per unit of projected spring area is usually more important. This mean spring pressure is equal to

$$\frac{\text{Total Spring Force}}{0.785D^2}$$

where D is the outside coil diameter.

For any spring of given index and wire shape, the curves in Fig. 2 can be used to find the maximum stress per unit spring pressure. Conversely, if the stress per unit pressure is known, several combinations of wire shape and spring index can be obtained. For example, the following are a few springs that are stressed to 600 psi per unit psi mean pressure:

Wire Shape	Spring Index, c
Round	5.5
$b/a = 1$	5.7
$b/a = 4$	11.0
$b/a = 0.5$	3.1



For any given outside coil diameter, D, the wire thickness a can be calculated for each value of c as follows:

$$a = \frac{D}{c + 1}$$

If, for a given outside diameter, more load capacity is required than is obtainable with round wire, the curves show that only rectangular wire with shape ratios greater than unity need be investigated. Thus, for c equal to 6, a round wire spring will have a maximum stress of 735 psi for each psi of mean spring pressure. For a rectangular wire spring of the same index and $b/a = 2$, this value reduces to 280 psi, which means that 2.6 times more load can be carried for the same stress. If b/a is increased to 5, the stress per unit pressure is 92, corresponding to an 8-fold increase in carrying capacity over the round wire spring of the same diameter. The plotted stress values were obtained by an exact theory and are therefore corrected for the effects of curvature and the pitch angles of the helical coil.

To illustrate some other advantages of the revised form of the stress data, consider a square wire spring of index 8 that must be replaced by another having a 50 percent larger capacity. From Fig. 2, the original stress-pressure ratio is 1400, and the new one is 933. If the new spring must use square wire, then the index should be 6.8. If the same inside as well as outside diameter must be kept, then b must be 1.38 times its original value. If, however, the original values of r and b must be retained, then a spring index of 5.6 and a shape ratio of 0.7 should be selected. These solutions can be read from the chart; previous methods would involve cut-and-try techniques.

Deflection Chart

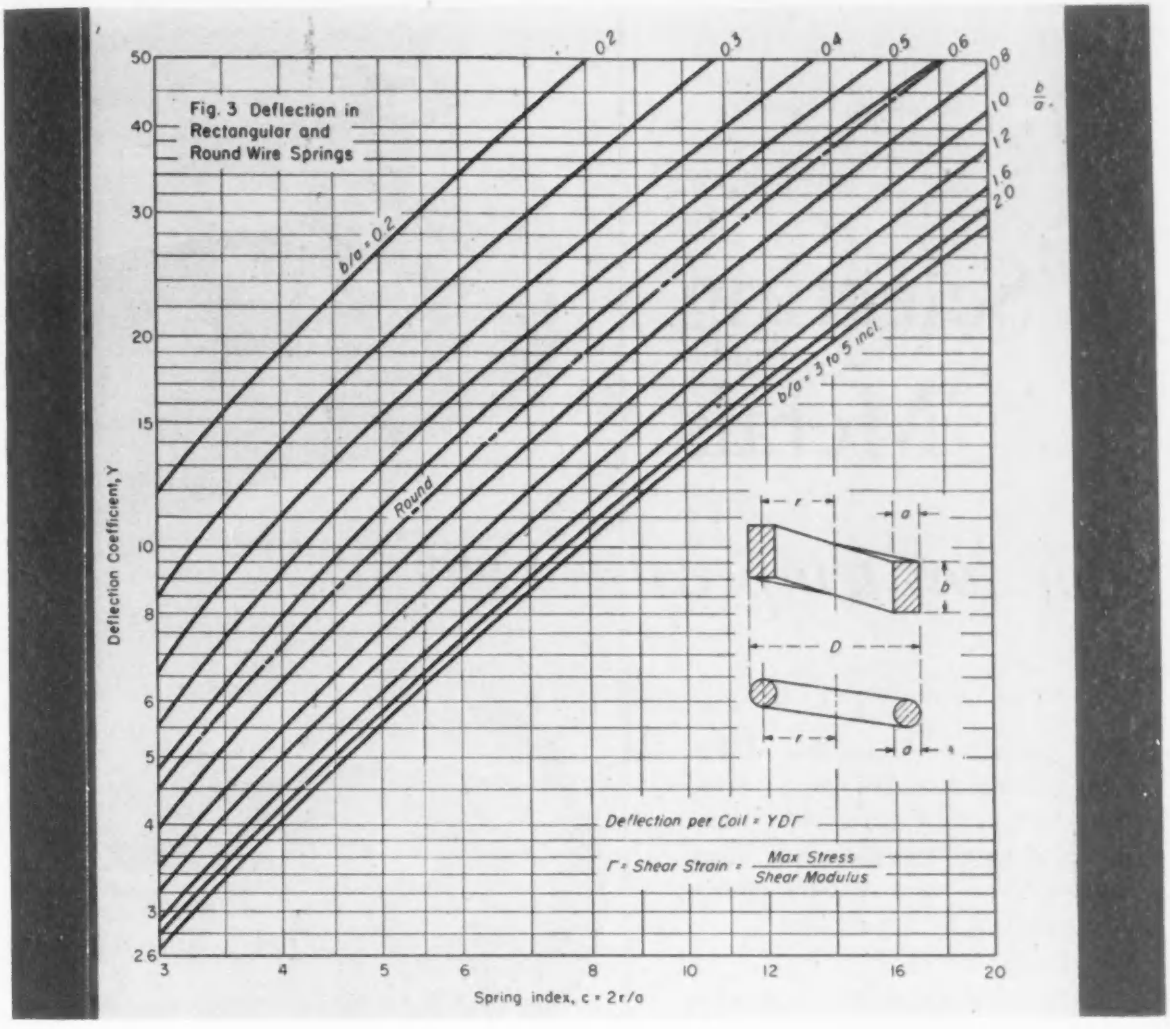
To facilitate making comparisons of the number of coils required, and thus the over-all length of springs of both types, the deflection characteristics are plotted as shown in Fig. 3. The original data for these curves were not, however, obtained by an exact theory because of the complexity of the derivation. For pitch angles of less than 10 deg, which represents most of the points on the charts, the estimated error in the deflection values is less than 3 percent. When the pitch angle exceeds 10 deg, more precise formulas must be used. For example, with an index of 3, and shape ratios between 2 and 3, the pitch angle varies from 12 to 18 deg, and the curves are in error by approximately 4 to 6 percent.

The use of this chart is illustrated as follows: Given the spring index and the wire shape, the value of a deflection coefficient Y can be found. From this, the deflection per coil is calculated by:

$$\text{Deflection per coil} = \gamma\, YD \text{ where}$$

$$\gamma = \text{shear strain} = \frac{\text{shear stress}}{\text{shear modulus}}$$

The deflection coefficient, therefore, is a quantitative measure of the deflec-



tion of a spring. Since a square spring of index 6, has a coefficient of 9.7, while a round wire spring of the same index has a coefficient of 12.9, the latter will deflect 33 percent more when subjected to the same maximum strain. As the wire shape increases from 0.2 to 5 for a given index, the deflection coefficient decreases by a factor of 5. Most of the change occurs at values of b/a less than 1. From $b/a_1 = 1$ to $b/a = 3$, the deflection coefficient changes only slightly and from $b/a = 3$ to 5 there is no further variation whatsoever. Most charts or formulas used to calculate deflection are based on load rather than strain. Since the same load produces a different strain or stress in springs of different wire shapes, calculation of deflection for a given stress was a tedious job.

When an application requires a maximum amount of spring deflection for a given length, the ratio of total spring deflection to the solid height is used for comparison purposes. For a round wire spring, this ratio can be expressed as

$$\gamma Y (c + 1)$$

For rectangular wire, however, the deflection ratio becomes

$$\frac{\gamma Y (c + 1)}{b/a}$$

Thus, when sufficient deflection cannot be obtained with round wire, rectangular wire with a shape ratio of less than unity may be the solution. The new charts quickly show the range of benefits that are possible.

For example, consider two springs of the same outside diameter, one of round wire and the other of rectangular wire with a shape ratio of 0.2. Both springs are made of the same material and are stressed to 15,000 psi per unit spring pressure. Using Figs. 2 and 3, the rectangular wire spring is found to have a deflection ratio 52 percent greater than the round one. Whether or not this difference is large enough to warrant the unconventional wire shape will depend upon the application.

For rectangular wire springs manufactured by cutting a spiral in tubular material, like the one shown in Fig. 1, the over-all length must take into consideration that the spiral is not carried to the extreme ends of the tube. This provides a solid end for fastening purposes. The number of active coils for such a spring is one less than the number of turns in the spiral. Because they are effective for transmiting large pulsating loads, both in tension and compression, springs of this type are used in fatigue testing machines with capacities up to 200,000 pounds. In the application shown, eight round wire compression springs of 6.25 inches outside diameter and 15.5 inches long were replaced with one rectangular wire spring having an outside diameter of 10.75 inches and a length of 12.5 inches.

Selecting Metals

for low temperature service

Fig 1—The above pressure vessels were tested for impact at —300 F by dropping a weight on them from a height of 5 feet. The carbon steel vessel (a) cracked in a brittle manner under a dropped load of 184.9 lb. Nickel steel and type 304 stainless steel vessels (b) stood up under a drop of 292.9 pounds.

The application of metals at low temperatures requires careful selection and design to avoid failure under dynamic loads. Factors affecting impact strength at room temperature increase in importance at subzero temperatures.

Steel selection requires particular consideration. The grain size, carbon content, alloy content, heat treatment and welding temperatures affect transition temperature.

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University of Texas

THE WIDESPREAD APPLICATION of metals at subzero temperatures has magnified the problem of low temperature embrittlement.

Cold embrittlement in metals is usually measured by its "shock limit" or "transition" temperature—the temperature at which impact strength becomes 50 percent of the room temperature value. The lower this transition temperature the safer the metal. Fig. 2 compares the subzero behavior of eight basic metals. It is evident that aluminum, copper, lead, magnesium and nickel and their principal alloys have satisfactory impact strength at all temperatures. With the exception of magnesium these metals show improvement in toughness at subzero temperatures. The cold temperature sensitive metals include iron, steel, tin, zinc, chromium, vanadium, tungsten and molybdenum.

Tin and zinc are the most temperature-sensitive metals. Pure tin undergoes phase changes between 55 F and —40F and can disintegrate into powder if small percentages of other metals are not present. Since it is not a structural metal its embrittlement creates few hazards, but its solders are to be suspected. Tin plate is usually not affected.

Zinc and its alloys are unsatisfactory for impact service below the freezing point. This accounts for many unexplained breakage of automobile fittings at low temperatures.

Wrought and ingot iron are also cold sensitive. Fig. 2 shows that pure iron has a transition temperature just below zero Fahrenheit. The curve for ingot iron in Fig. 5 illustrates the sudden nature of embrittlement.

Gray cast iron is normally brittle so

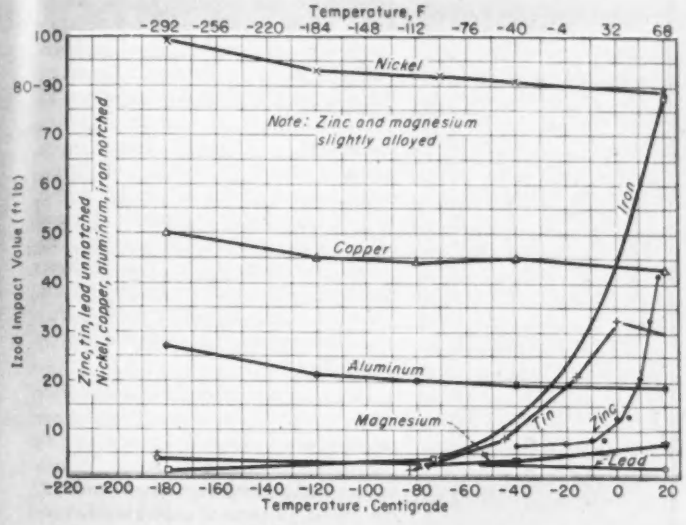


Fig 2—Impact strength of pure metal at low temperatures.

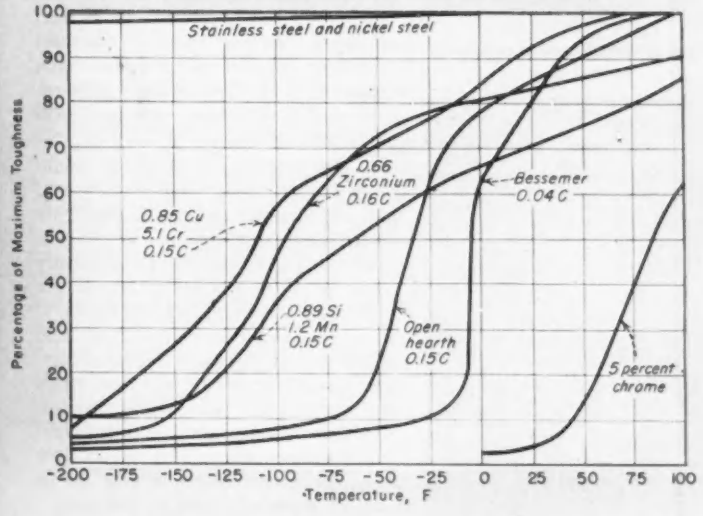

Stainless steel and nickel steel
0.66 Zirconium 0.16C
Bessemer 0.04C
0.85 Cu 5.1 Cr 0.15C
0.89 Si 1.2 Mn 0.15C
Open hearth 0.15C
5 percent chrome
Percentage of Maximum Toughness
-200 -175 -150 -125 -100 -75 -50 -25 0 25 50 75 100
Temperature, F

Fig 3—Low temperature impact resistance of steels.

Table I—Impact Strength—Temperature Relationship of Various Metals

Test Temperature, F			
TIN AND SOLDER (Unnotched)	Charpy Impact Value ft. lb.		
	Tin	Solder	
122	28.2	....	
70	....	15	
32	32.5	....	
3.2	21.0	....	
−49	8.0	....	
−117	2.2	....	
−292	....	2	
ZINC BASE ALLOYS	4% Al	4% Al, 1% Cu	
68	42	44	
50	31	41	
32	7.6	39	
14	3.3	18.3	
−4	2.5	3.6	
−40	2.1	2.4	
MEDIUM-CARBON STEEL (Notched)	0.35C[3]	0.45C[3]	Forging
77	....	16	....
70	81	....	38
32	64	12	....
−2	40	....	....
−4	....	10	....
−40	....	9	11
−67	22	....	....
−94	....	....	7.5
−108	....	8	....
−113	8	....	....
HIGH CARBON STEEL (Notched)	Normalized	Quenched	
80	5	....	
77	....	10	
32	6	6	
−4	5	8	
−40	2	5	
−108	3	4	
WROUGHT AND INGOT IRON	Notched Izod Impact Value, ft. lb. Wrought Iron	Armco Iron	
70	....	78	
62	65	....	
32	28	....	
−22	13	....	
−58	5	....	
−101	....	4	
−108	3	....	
−180	....	1.5	
LOW CARBON STEEL	Notched Impact Value, ft. lb. Rolled[1]	Cold Drawn[2]	Cold Drawn[2]
		0.10C	0.17C
70	52	28	54
−20	....	8.5	16
−25	44	....	....
−40	....	6.5	12
−51	1.5	....	....

[1] Charpy [2] Izod [3] Charpy with Izod notch

low temperature introduces no new risks. Unlike wrought iron its impact strength is reduced only 25 to 30 percent at —300 F. Malleable cast iron displays a similar reduction in shock resistance.

Steel Selection

Where shock loads accompany low temperatures, steels should be chosen carefully. The following suggestions are recommended to aid in their selection:

1. Specify high purity steel, because transition temperatures are raised by impurities such as dissolved oxygen and nitrogen. Enough aluminum should be stirred into the molten metal to both degas it and leave traces in the chemical analysis. Steels so "killed" are safer than semi-killed, and semi-killed are safer than unkilled or silicon-killed steels. All are better than "rimmed" steels. Phosphorous, slag, and sulphur are equally harmful, so open hearth or electric steels are preferable to Bessemer grades. Mass-produced parts of "free-cutting" steels are to be suspected.

2. Maintain a fine-grained structure. Fine grain size follows thorough killing; the aluminum residue forms extra nuclei for metal solidification and forces formation of smaller grains. Additions of vanadium, zirconium, titanium, or molybdenum also reduce grain size. Heat treatment to refine the grain is beneficial, while slow cooling, overheating, or any heating sequence that increases grain size should be avoided.

3. A low carbon content is advantageous. Except where strength and hardness require more, a carbon content below 0.15 percent seems best.

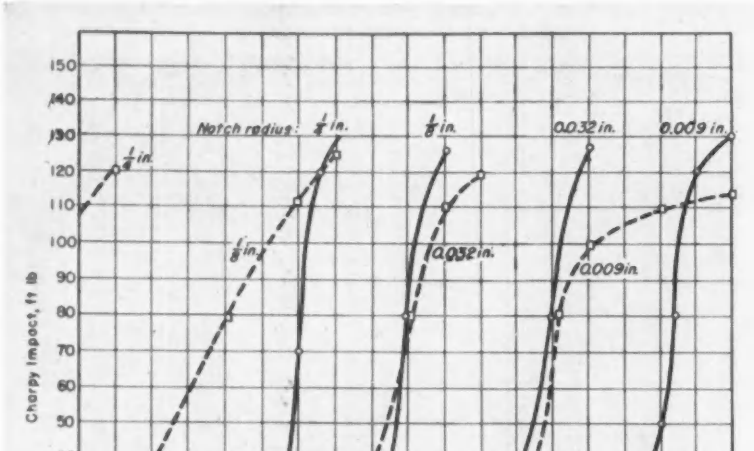


Fig. 4—Effect of notch sharpness on impact resistance of a carbon and nickel steel.

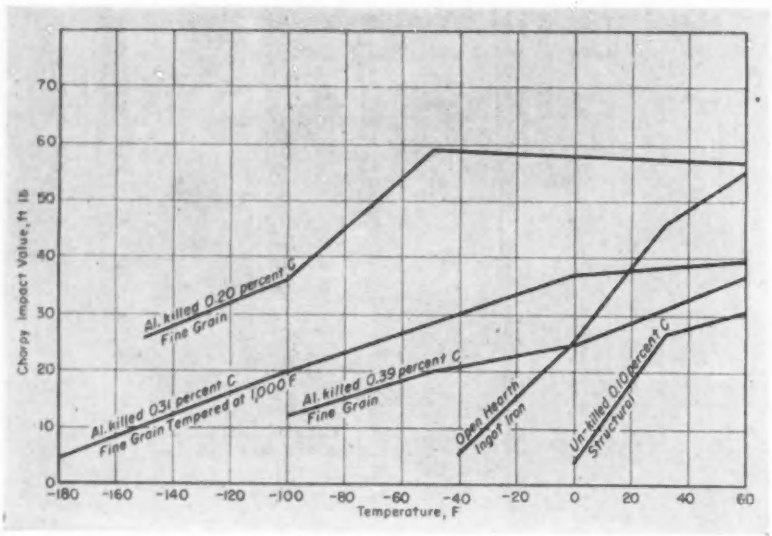


Fig. 5—Effect of carbon content, purity and grain size on impact resistance.

Greater amounts foster carbide segregation and creation of internal notch stress raisers. Some authorities recommend a manganese/carbon ratio of at least four. The effect of carbon content, purity and grain size on low temperature impact resistance is shown in Fig. 5.

4. Steels should be hardened and tempered if possible. The microstructures of ferrite and pearlite from annealing or normalizing have both large grain size and hard carbide inclusions. The hardening operation relieves prior fabrication stresses and transforms the grain into fine needles of martensite. Tempering around 400 F relieves quenching stresses and creates the strongest and hardest phase, but maximum cold-toughness is obtained by tempering near 1250 F.

Unfortunately, most steel is delivered in the "as rolled" or normalized state.

5. Use alloys only when necessary. When pure, fine grained, hardened steel is used, transition temperatures for carbon steels are lowered to perhaps —90 F, compared to —40 F for bulk tonnage grades. Thus most applications do not require alloys. However, where service and temperature are severe, the use of low-alloy high-strength steels is justified. These are fully killed fine-grain low carbon stock containing small percentages of nickel, chromium, molybdenum, silicon, manganese, copper, zirconium, or vanadium. These elements purify, refine, and strengthen the metal; around —100 F these steels are markedly superior to carbon steels. Fig. 3 shows the behavior of three such metals. When hardened and tempered they are satisfactory to approximately —150 F.

For ultra-low temperatures and very severe service, the nickel steels are recommended. In many cases a 2 or $3\frac{1}{2}$ percent nickel steel will suffice. Where strong embrittling factors are present, the $8\frac{1}{2}$ or 13 percent nickel steels may be used. Fig. 6 compares the properties of nickel steels, while Fig. 4 shows nickel's excellent effect upon notch sensitivity. The 13 percent nickel steel is amply corrosion resistant for most purposes, so use of stainless steel, monel or inconel is seldom justified. Frequently, aluminum or copper will perform satisfactorily.

When used, stainless steels should be carefully chosen. The ferritic and pearlitic straight chromium steels are severely temperature sensitive; Fig. 3 shows such a chrome alloy, apparently ferritic, with its transition temperature well above freezing. Typical pearlitic 12 percent chromium alloys have zero as their shock limit temperature, whereas the austenitic stainless steels of 18-8 variety are highly recommended low temperature metals. Nevertheless, their use where carbon, low alloy, or nickel steels would do is needless waste of scarce ingredients.

6. Follow the codes in designing pressure vessels. Most states recognize the 1948 ASME Code for Unfired Pressure Vessels, but a few require the older one. In general, the base metal at its working temperature should have a minimum Charpy keyhole notch impact value of 15 ft. lbs. or Izod "V" notch value of 18 ft. lbs.

7. Don't take welds for granted. Welds increase notch sensitivity by introducing both impurities and rough surfaces. For best results inclusions of hydrogen from electrode coatings and nitrogen from the atmosphere should be minimized, the inert and submerged arcs being preferable to ordinary welding. Gases in solution can be expelled by soaking two-hours at 1100-1170 F, but heating below about 840 F should be avoided as it con-

verts dissolved nitrogen into nitride inclusions. A manganese/carbon ratio of about 7/1 reduces such precipitation. Finally, welds can be machined smooth to reduce surface effects.

Welds also create residual stresses from uneven cooling. Preheating, welding techniques which distribute the heat and expansion, and thorough peening are partial preventives. Where possible, stress-relieving at an adequately high temperature is recommended—perhaps simultaneously with the degassing noted above.

Welds affect surrounding metal to a degree depending upon the number of passes of the electrode and the temperatures attained, and even welds with refined grain are surrounded by coarsened base metal of markedly higher transition temperature. Hence, fine grained killed steel is recommended for all welded structures subject to subzero impact service. Degassing and stress-relieving, followed if possible by a grain refining heat-treatment, would be added protection. Size and cost are common objections to these precautions.

Generally, welded structures should be given better materials than equivalent non-welded ones. Killed steels should replace ordinary grades; low alloy should replaced killed steel; nickel steels should replace low alloy; and stainless steel or Monel should replace nickel steels. The electrodes should be of low hydrogen type and of higher strength than the base metal, and should contain nickel to reduce notch sensitivity. Thus, mild steels of any grain size are advisedly welded with low nickel-molybdenum rods, low alloys and nickel steels with similar material, and high nickel steels with stainless rods.

Critical Design Factors

In the design of metal equipment and parts for low temperature impact service embrittlement agents other than low temperature must be considered. These include (1) impact velocity (2) section thickness (3) presence of notches or other stress raisers (4) residual stresses. In any situation, the transition temperature is raised by the influence of these factors. Consequently as the transition temperature is approached their effects become increasingly dangerous.

IMPACT VELOCITY. Brittle failure occurs when stressed metal cannot deform plastically. Since plastic deformation is time-consuming the higher the velocity of impact the less ductile the metal will behave. In explosions all metals seem brittle, i.e. have high transition temperatures. The effect of striking velocity on SAE 1020 mild steel at —110 F is typical: at a velocity of 12.8 ft per sec the Charpy impact value is 40 ft-lb and at a velocity of 18.1 ft/sec it reduces to 3.5 foot pounds.

SECTION THICKNESS. Thin stressed members distribute the load relatively uniformly over their cross-sections while thick members achieve this equal distribution less easily. Often the edges of heavy members become overstressed and fail before the interior is fairly loaded—especially when the load is eccentric or is applied rapidly. Thicker members also suffer higher stresses under equal bending deflection.

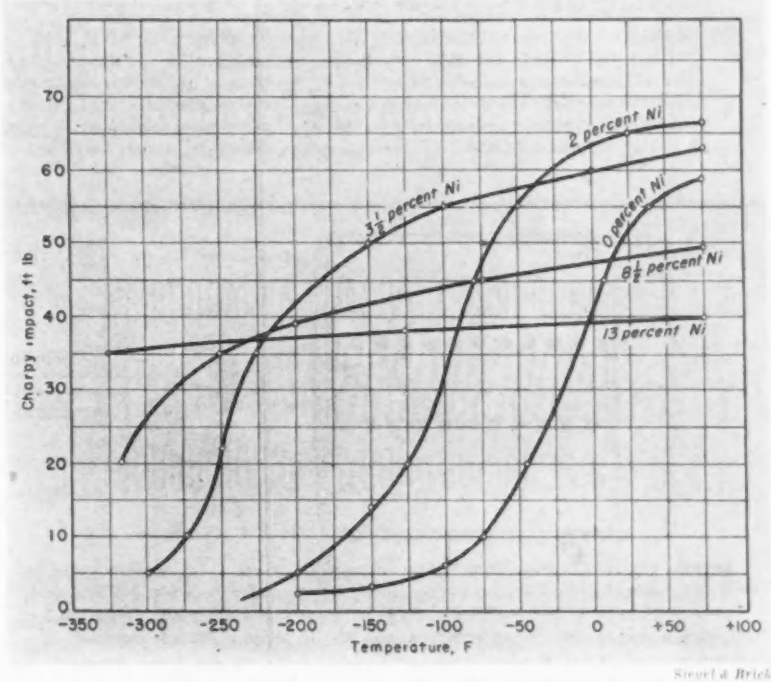
From the standpoint of quality thick sections are frequently inferior as well. Less rolling, drawing or forging has occurred and more porosity and ingot defects persist. In heat treatment less uniformity is attainable with thick sections because of their slower cooling.

STRESS RAISERS. Discontinuities in metal, such as notches, scratches, cracks or other surface defects, distort the normal uni-axial stress flow and create triaxial stresses concentrated at the apex of the defect. These stresses cannot be redistributed by normal deformation and the stress area becomes an origin for cracks when dynamically overloaded. Tool scratches, file marks, punch marks, and sharp corners prove dangerous in all designs subject to shock or alternating stress.

In general, the sharper and deeper such defects are, the higher the transition temperature of the metal is raised. Cast iron has innumerable internal notches because of the presence of graphite flakes and consequently is brittle at all temperatures. Carbides in high carbon steel and phosphides in Bessemer products have similar effects. In Fig. 4 are shown the effect of notch size and temperature on a carbon and nickel steel.

INTERNAL STRESSES. Wrought metal is pre-stressed by cold rolling, drawing, bending, or forming, and castings by unequal cooling rates in their parts. In weldments residual stresses from contraction vary almost directly with the weight of metal added or the number of passes of electrode. Bolted members are pre-stressed by tightening, and shrink-and force-fits by the degree of interference.

In static loading such locked-in stresses are relieved when sustained working stresses force local areas above the elastic limit and cause deformation which redistributes the load. But in impact service redistribution largely fails, especially where notch effects hinder plastic flow. Thus, structures subject to low temperature impact must be flexible enough that such stresses relieve themselves naturally. Where rigidity is essential, fabrication pre-stresses should be prevented or removed by heat-treatment.



Steel & Brick

Fig. 6—Effect of nickel on impact resistance of normalized low carbon steel.

Thirteen Ways to Use M

Sketches serve two purposes: (1) Illustrate unique as well as typical applications; (2) S

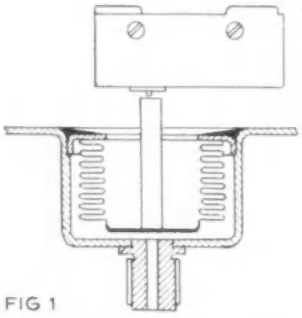


FIG 1

ACTUATE GAGES and Switches. Pressures can be as large as 2,000 psi. Maximum value should exist when the bellows is near free-length.

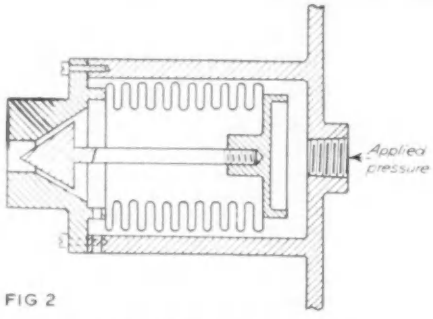


FIG 2

FLOW CONTROL. Variations in pressure adjust needle in flow valve. Also shows how bellows can be packless seals for valve stems and shafts.

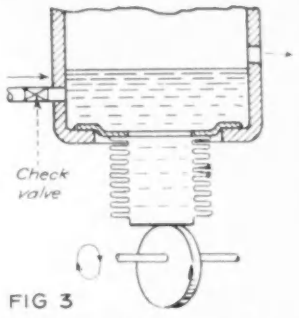


FIG 3

METERING DEVICE. Dispensing machines can use bellows as constant or variable displacement pump to measure predetermined amounts of liquids.

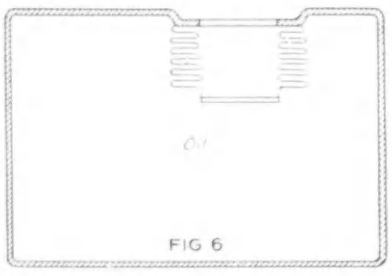
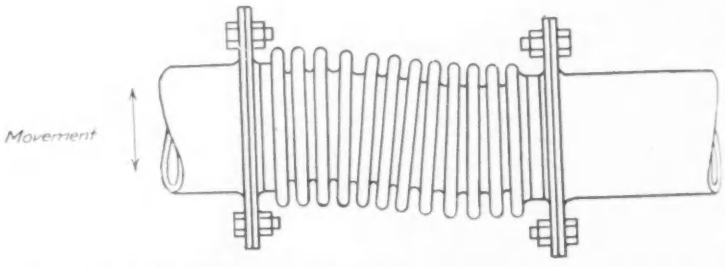


FIG 6

ABSORB EXPANSION OF FLUIDS OR GASES. Transformer (above) uses bellows to absorb increases in volume of oil caused by thermal expansion. Single controls of this type can operate from —70 to 250 F or from 0 to 650 F.



FLEXIBLE CONNECTOR. Suitable for wide range of applications from instruments to jet engines and large piping. Bellows absorb movement caused by thermal expansion, isolate vibration and noise as well as permit misalignment of mating elements. Wide variety of sizes and materials are now possible. Units are now in use from $\frac{1}{4}$ to 72 inches in diameter, made from such materials as brass, phosphor bronze, beryllium copper and stainless steel.

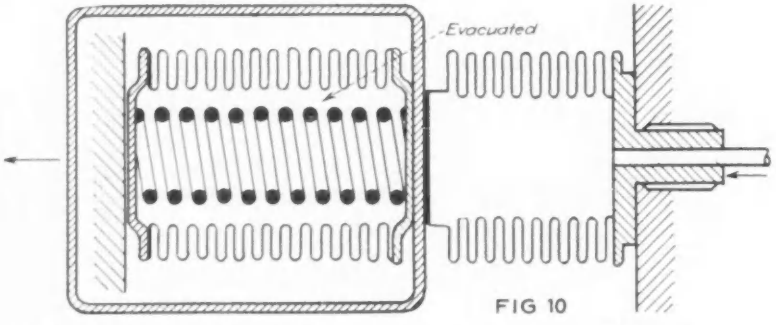
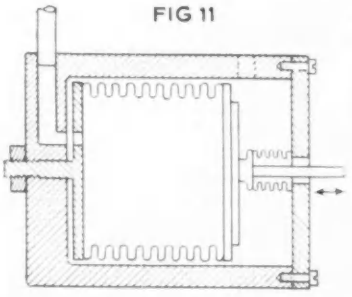


FIG 10

PRESSURE COMPENSATOR. Effect of ambient pressure can be eliminated in a pressure measuring system by matching the area of a pressure bellows with that of an aneroid and combining the two into a single assembly. Errors caused by ambient pressure can be held to a max of one percent. Present materials permit aneroid operation from —70 to 450 F.

FIG 11



PRESSURE MOTOR. Similar to Fig 2. Bellows used instead of piston and cylinder arrangement. Eliminates effects of leakage and friction. Long stroke can be provided with sensitive response.

Metallic Bellows

E. PERRY CUMMING
Bridgeport Thermostat Division
Robertshaw-Fulton Controls Company

(2) Show how the movement of bellows can be transferred to other elements.

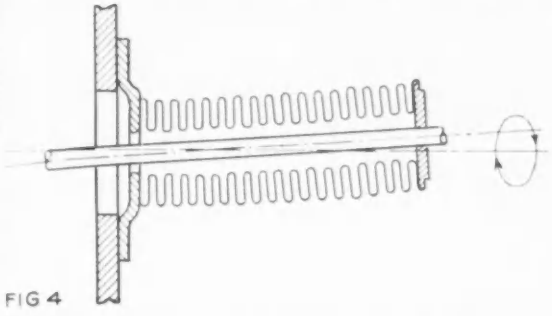
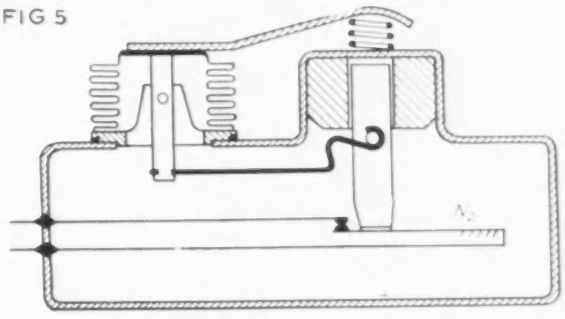


FIG 4

FLEXIBLE COUPLING. Bellows can transmit torque through oblique shafts with negligible amount of backlash or can be used to transmit circular motion through the wall of a sealed container as shown above.

FIG 5



HERMETIC SWITCH. Bellows provide a gas tight flexible member through which motion can be transmitted into a sealed assembly. Flexibility and long life are important characteristic of these elements.

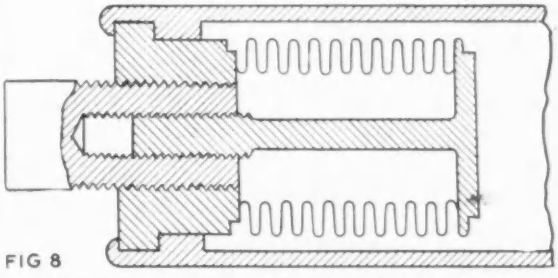


FIG 8

SEALED ADJUSTMENT. Accurately calibrated adjustments inside sealed instruments are possible by means of single or compound threads. To meet varied installation requirements, bellows are available with ends prepared for ring or disk end plates of standard or special design. These plates are fastened by brazing or welding techniques.

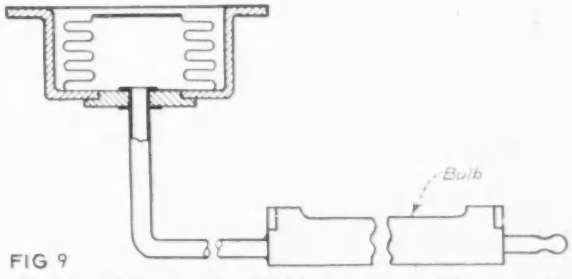


FIG 9

VAPOR PRESSURE THERMOSTAT. Small dia bellows offer large movement over a relatively small, adjustable temperature range. Can be filled so as to be unaffected by overruns in temperature. Compensation for changes in ambient temperature is unnecessary whether this temperature is above or below the value selected for control purposes.

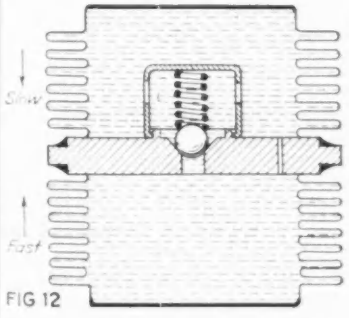


FIG 12

TIME DELAY MECHANISM. A check valve and proper size bleed hole between two liquid filled bellows allows fast motion in one direction and slow motion in the other direction.

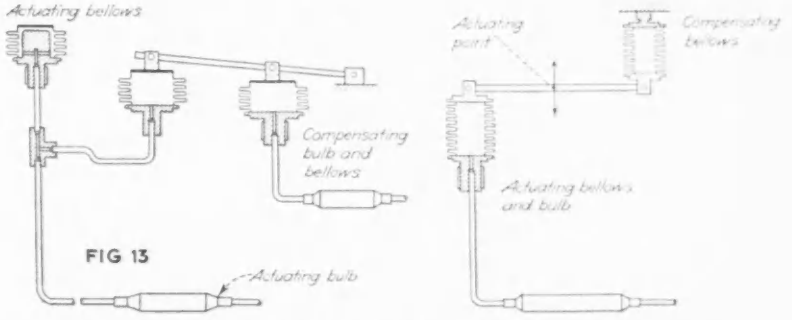


FIG 13

AMBIENT TEMPERATURE COMPENSATION. Two methods are shown. The left one uses two bellows in the actuating system. One is driven by the compensating assembly and correctly positions the actuating bellows as ambient temperature changes. The other method uses a floating lever whose mid-point is positioned by both the actuating and compensating bellows.

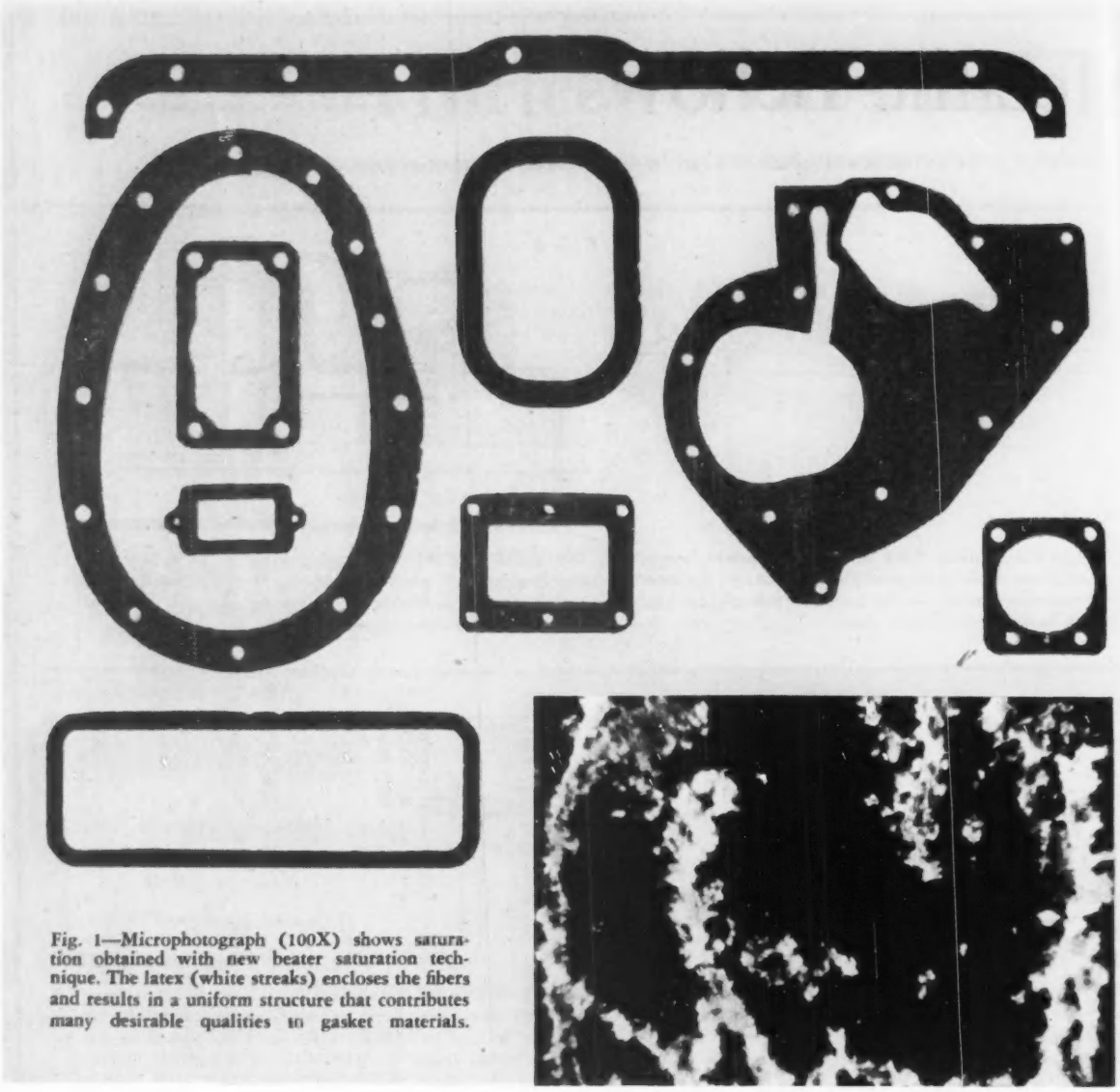


Fig. 1—Microphotograph (100X) shows saturation obtained with new beater saturation technique. The latex (white streaks) encloses the fibers and results in a uniform structure that contributes many desirable qualities to gasket materials.

Beater Saturated Gasketing Materials

FIBER GASKETING MATERIALS, produced by a modification of the beater saturation process, have recently been developed by the Armstrong Cork Company. The sheet materials as a result of this improved process have high compressibility, high crush resistance, imperviousness, flexibility, and uniform structure.

Fibers are treated in the beater saturation process with water dispersions of rubber or resin, before they are formed into paper on the wire of conventional paper making equipment. This treatment locks each fiber, as shown in Fig. 1, in an even coat of rubber before the sheet is formed and results in a uniform distribution of the saturant throughout the sheet.

By contrast, in the ordinary saturation process the paper is formed first and then dipped in the saturation bath. Papers so saturated must be soft and porous to absorb the saturant; even then the amount of saturant taken up by the paper is small when compared with the saturation possible with the new technique. Often the surface of the paper filters out much of the saturant, leaving a heavier coating on the

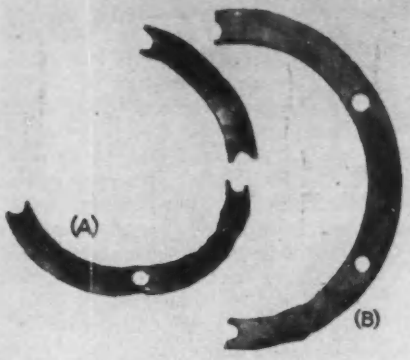


Fig. 2—Both gaskets were used for six months in a gear pump circulating hot hydraulic oil. (A) Plant fiber gasket dried out, shrunk and leaked after losing its glycerine plasticizer. (B) Beater saturated fiber sheet gasket was practically unaffected, and no leakage occurred at flanges of the pump.

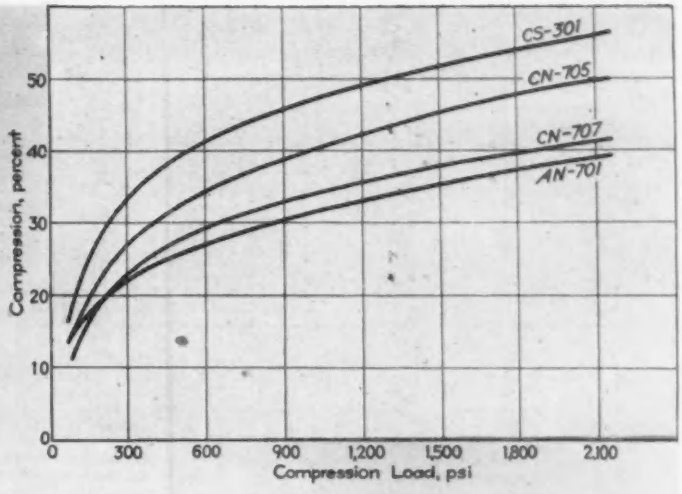


Fig. 3—Load compression curves showing percent of compression with increasing load. Three upper curves are for cellulose fiber beater saturated sheets; lowest curve is for an asbestos fiber beater sheet.

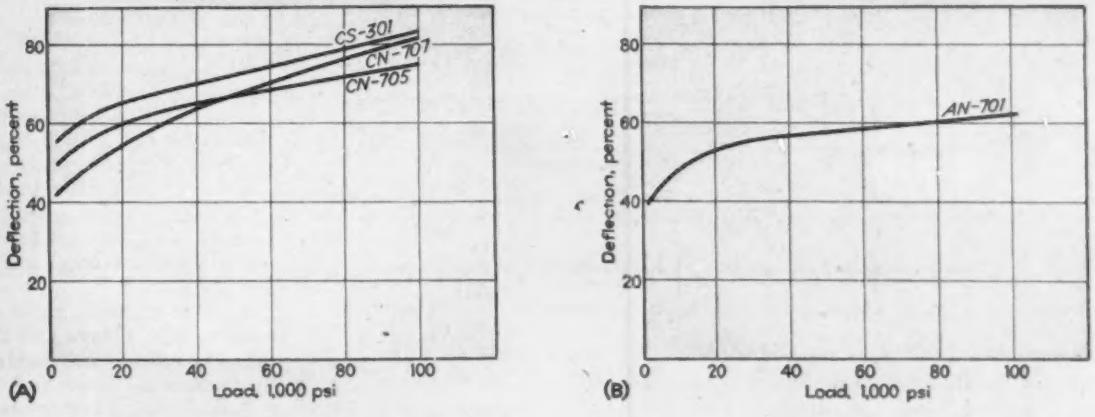


Fig. 4—Load compression curves. (A) Cellulose fiber beater saturated sheets. (B) Asbestos fiber beater saturated sheet.

Cellulosic or asbestos fibers treated with water dispersions of rubber or resin, prior to being formed into sheet, provide the base for new classes of gasketing materials having high tensile strength, good dimensional stability, high crush resistance, and uniform compressibility with load.

surface than in the center of the sheet.

With the beater saturation technique in the past, it was difficult to deposit enough saturant on the fibers to permit making a tight gasket sheet. If enough was used to make the sheet impervious, much of the saturant formed in agglomerates of rubber or resin rather than in a coating on the surface of the individual fibers. The new beater saturation techniques permit the deposition of larger amounts of saturants on the fibers to make completely impervious sheets. Previously a maximum of only 20 to 25 percent of saturant by weight was possible, however, the new technique permits the use of 100 percent or more saturation.

Various types of fibers, saturants, and fillers may be combined and distributed uniformly throughout the sheet to create an almost unlimited variety of gasket sheet materials. Commercial sheets are being made in which synthetic rubbers are deposited on cellulose fibers and on asbestos fibers. With the large range of fibers, saturants, and fillers available, almost any industrial need can be met with a sheet having the desired properties.

Table I—Laboratory Leakage Test Data

All gaskets are 1/32 in. thick

Bolt Torque lb-in.	Leaking Pressure, psi		
	Fiber-Cork Buna S Sheet	Fiber-Cork Buna N Sheet	Fiber-Cork Buna N Sheet containing a high proportion of rubber
20		100	100
30		100	100
40	100	100	325
50	300	250	950
60	725	975	1800
70	850	1250	no leaks at 2,000 psi
75	1100	no leaks at 2,000 psi	no leaks at 2,000 psi

Table II—Typical Applications of Beater Saturated Gasket Materials

MATERIAL	APPLICATION	REASON FOR USE
Buna N saturated cork-fiber sheet	Gear case gasket on agitators on Penicillin manufacturing equipment.	Keeps lubricants out of antibiotics. Gives positive assurance of no leakage.
	Oil control valves and metering equipment.	Good resistance to corrosion. Assures tight joints.
	Gear case gasket on washing machines.	Tight seal to avoid leakage.
	Oil pan on small farm equipment.	Tight seal at corners of pan.
	Cover gasket on hydraulic oil reservoir made for assembly on farm tractors.	Resilient gasket material seals flanges under vibration and shock.
	Cylinder block gasket on diesel engines.	Resistant to both heat and oils. High compressibility is needed.
	Washers on pressure lubricating devices.	Resilient and seals with little flange pressure.
Buna S saturated cork-fiber sheet	Oil pan gasket on gasoline engines.	No oil seepage keeps motor block clean in dusty applications.
	Gaskets on water softeners.	No tendency to extrude from the flanges.
Buna S and Buna N saturated fiber-cork materials	Deep and shallow well water pumps.	Long life and good corrosion resistance.

Ordinary cellulose, or plant fiber, sheets frequently lose the binder through the solvent action of fluids. Generally, these cellulose papers have been passed through a saturating bath of glue and glycerine, followed by a tanning treatment to make the glue insoluble. Water is severe in its solvent effect. Even gasoline and oils work to extract the glycerine plasticizer. As shown in Fig. 2, with the loss of the plasticizer, the gasket dries out, shrinks, and leaks.

In the new beater saturated materials, the saturants are non-volatile and non-extractable. In applications where glue-glycerine sheets shrink and fail, no apparent change occurs in sheets of materials made with the new technique. Also, the saturants in these new materials are unaffected by changes in humidity, thus giving these sheets an improved dimensional stability. This characteristic is advantageous when replacement parts must be stored for months before use.

The cellulosic and the asbestos fiber sheets made by the new process each combine many of the good qualities of the other, although each is designed for a different job. Included in their advantages are:

1. Compressibility. The high compressibility resulting from the method of forming the sheets is further increased by the addition of finely ground cork particles in weights of up to 33 percent of the total. Asbestos sheet formed by this process has unusual compressibility. In Fig. 3 are shown load compression curves for several of these materials. These compositions work equally well on light metal or stamped flanges and on rough heavy flanges. In lightweight construction, they seal without distorting the flanges between the bolts. In heavy flanges, they completely fill imperfections in the flange surfaces.

2. Crush Resistance. Because of the uniform structure of the sheets and their resilient binder, they will withstand compressive loads up to 100,000 psi without damage. In heavy flange construction, where uncontrolled bolting torque, unevenness in the flanges, or lack of parallelism between the flanges often occurs, such crushing loads are often present at local point

The load deflection curves show in Fig. 4 were obtained with dis specimens of 1 sq in. area when loade in a Baldwin Southwark universal tes ing machine at the rate of 10,000 l per minute. The new beater saturate gasket materials showed no sign o failure under full loads of 100,000 l

3. Flexibility. These new materials have excellent handleability, which is of value in the beater saturated as bestos types. Whether of asbestos or cellulose fiber, these materials can be bent double without cracking or pip ing and can then be used without los of sealing properties.

4. Sealing Properties. The homogeneous and nondirectional structure of both the asbestos and cellulose fiber sheets provides good sealing properties.

The sealing ability of the cellulose fiber materials under light flange pressures is indicated in Table I, which gives data derived from a laboratory leakage test. For this test, a $1\frac{7}{8}$ in. O. D. by $1\frac{1}{8}$ in. I. D. by $\frac{1}{32}$ in. thick gasket was assembled between two $\frac{1}{2}$ in. thick steel flanges held together by four $\frac{1}{4}$ in. bolts. Torque was applied to the bolts as indicated in Table I.

5. Die-Cutting Properties. Both materials can be die-cut without leaving whiskers. The asbestos materials contain no clumps of dry asbestos (unimpregnated with rubber binder) to prevent clean die cutting.

6. Form. The materials are available in sheets, rolls, ribbons and die-cut shapes. The cellulose materials are made in thicknesses up to and including $\frac{3}{32}$ in. in single homogeneous sheets (not laminated); and the asbestos sheets in thicknesses up to $\frac{1}{16}$ in. Compressed asbestos sheet packing material in continuous roll and ribbon form offers economies in fabricating in automatic feed presses.

Some typical applications of beater saturated gasket materials are given in Table II. In certain applications, gaskets made of these materials have stopped seepage of oil on valve covers and crank case pans of gasoline engines. Without oil seepage the motor blocks remain clean.

These new materials contain no hygroscopic or corrosion-causing chemicals, therefore, the contacting flanges remain clean and dry. The cellulose fiber sheets have proven to be effective in many applications where corrosion on light metals was undesirable.

This new group of materials is apparently unique in that they not only effectively seal lightweight flanges under light bolting pressures, but also are not damaged by the heavy pressures found in heavy flange construction.

THE FIELDS of application of injection molded thermo-plastics are greatly increased through the use of numerous established post-molding treatments. These finishing techniques include decoration by means of lacquering, printing and application of decalcomania; metallizing; destaticizing; annealing; machining and assembly. The first three classifications will be discussed in this article. The other techniques are mentioned briefly later. Some of the advantages of these post-molded treatments are:

(1) Protection against abrasion or chemical attack.
(2) Increased surface heat and electrical conductivity.
(3) Protection against accumulation of statically charged dust particles.
(4) Flexibility of Production. One die can be used for numerous items by utilizing various after-treatments.
(5) Increased functionality through use of contrasting colors for dial calibrations or in decorative schemes.
(6) Salvage of otherwise rejected parts. Weld lines, air bubbles and overrun colors can be marked with suitable coatings.

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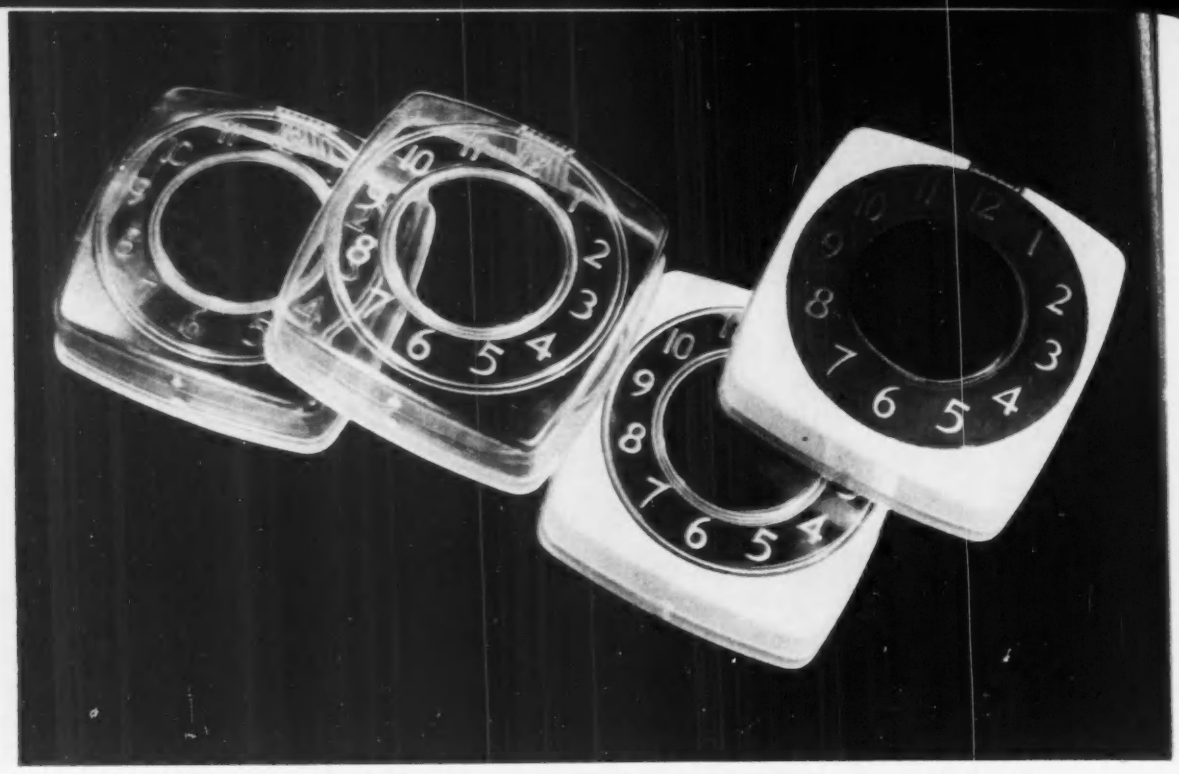


Fig. 1—Lacquering of clock faces to produce desired color effects is done in several steps. The lacquer is applied to the rear of the article. This produces pleasing three-dimensional effect and also protects the lacquer from damaging abrasion. General Products and Sessions Clock Co.

Post-molding treatment agents or techniques will vary with the type of thermoplastic. There are no universally applicable compounds which can be employed. Nylon and polyethylene, for example, are difficult to cement because of their excellent resistance to the general adhesive compound.

A suitably clean plastic surface is the basic requirement for satisfactory results in the application of these techniques to molded articles. Mold release agents and accumulated dust and grease will require removal to obtain maximum adhesion. Also, all compounded lacquers, inks and cements must be formulated to insure chemical compatibility with both the resin and its plasticizer, if present. The degree of rigidity is another important characteristic which must be considered because of its effect upon film adhesion.

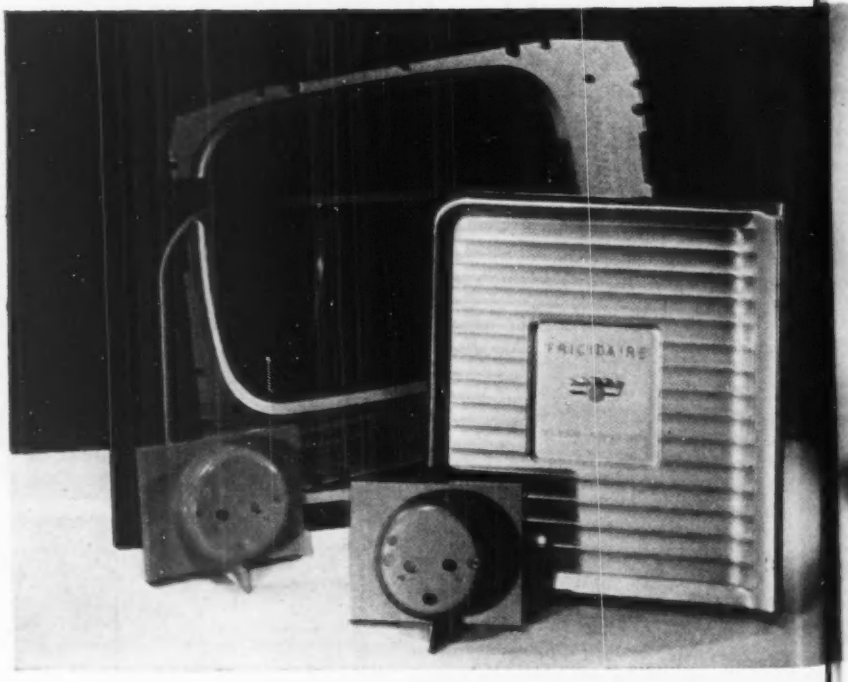
Decoration

Decoration, the most popular of the post-molding treatments, includes lacquering, printing, hot stamping and the application of decalomania. The variations in color obtainable by these techniques increases flexibility of product design.

Lacquering of plastics requires that the coating adhere to the object through mild chemical attack of the organic solvents upon the surface. This attack should not be sufficient to produce crazing, which can result in weakened pieces. For plasticized resins the lacquer formulation must be compatible with the plasticizer. Drying time, adhesive qualities, gloss, mar resistance and color fidelity are other factors or requirements to be considered in the selection of lacquers.

Lacquers can be applied by spraying, dipping, wiping, rolling or brushing. Spraying is the most generally

Fig. 2—A lacquer coating is applied to various appliance parts for decorative and protective purposes and for prevention of excessive dust accumulation



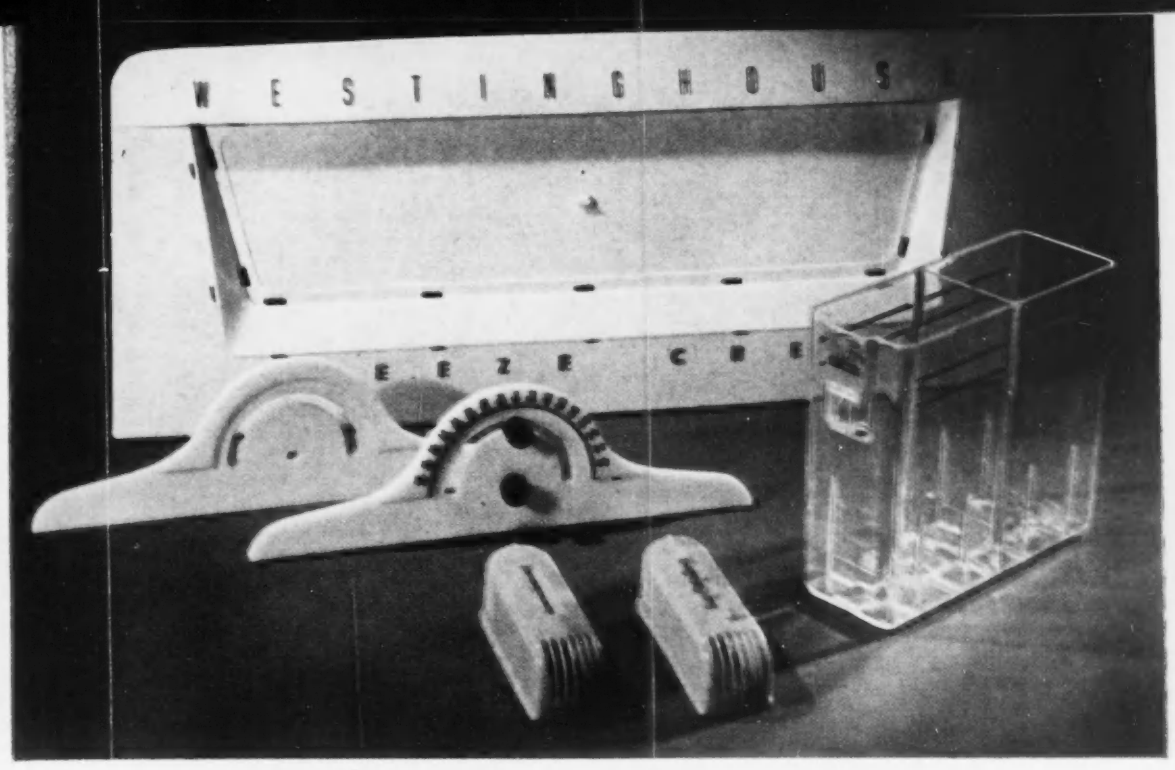


Fig. 3—Printing of plastic articles increases visual contrasts. Scale graduations, markings and trade names can be printed in various colors. The wiped-on coatings shown above are applied to molded inlays and the excess wiped off.

acceptable method because of its speed and versatility. By the use of stencils or masking tapes complicated designs, even in multiple colors, can be rapidly applied without afterwiping of parts. The successive stenciling of the crystal styrene clock face in Fig. 1 is an example. This technique finds wide use in radio and television parts, automobile insignia and horn buttons and escutcheons on major household appliances. Where handling and subsequent scratching are major problems temporary strippable coatings are applied over the lacquer coat.

Automatic equipment is available that can spray up to 900 pieces per hour in as many as four colors, or 3,600 pieces per hour in one color. Production lines, utilizing individual spray booths and drying tunnels, are easily installed.

Dipping is sometimes used when a complete coat is desired on an item. This method was popular for coloring styrene prior to the adoption of dry coloring. Dipping baths may be either lacquer compounds or water solutions of some special dyes. When conventional organic lacquer baths are used, thicker solutions than would be employed for spraying are advisable to get a more even coat.

Wiping in lacquer, or "puddling", is useful for producing scale or dial graduations. Lacquer is applied to the entire surface of the part and the excess wiped away, leaving color in the recessed portions only. Semi-solid stick forms of lacquer are available for wiping.

Rolling is the converse of wiping. The lacquer is applied to a porous roller and rolled onto raised surfaces, similar to the inking of a printer's galley proofs. The main disadvantage of this method is that the lacquer is vulnerable to abrasion due to its exposed location. Some protection is

Fig. 4—Trade name and graduations on radio was applied by technique of hot stamping. Gold colored foil was embedded into the plastic. General Electric Co.

POST-MOLDING TREATMENTS FOR THERMOPLASTICS

TREATMENT	DESCRIPTION	METHODS	EQUIPMENT REQUIRED
LACQUERING	Application of organic coating to all or part of plastic surface in one or more colors	Spraying, dipping, wiping in, rolling, brushing	Suitably compounded lacquer, masks, spray guns, dip tanks, rags, cleaning mats., rollers, brushes, bottle, drying ovens
PRINTING	Application of adhering ink to all or part of plastic surface in one or more colors	Offset and flat bed presses, rubber stamping, silk screening, hot stamping	Suitably compounded ink, press, type or plate, rubber stamps, silk screen stencils and rack, hot stamp press and dies
DECALCOMANIA	Adhesion of printed paper or plastic sheet to plastic molding	Attachment by means of adhesive or coating over with clear lacquer	Prepared decals, roller, spray gun, clear lacquer
METALLIZING	Application of metallic coating or coatings to all or part of plastic surface	Electroplating, spray reduction, vacuum metallizing, cathode sputtering	Plating metal in suitable form, chemical solutions plating tanks, spray guns, vacuum vessel and pump, masks
DESTATICIZING	Surface coating plastic item with film embodying improved electrical conductivity to drain off static charge as received	Dipping, spraying, buffing, wiping, radioactive ionization of surrounding air	Destaticizing compounds, tanks, spray guns, rags, buffing wheels
ANNEALING	Minimization of residual strain resulting from sudden quenching of thermoplastic during injection molding process	Water, air, or infra-red application of controlled heat	Thermostatically controlled water tank, hot air oven, or infra-red lamp bank, timer
ASSEMBLY	Integration of various plastic and/or other components into final unit	Cementing, heat sealing, threaded items, hinges, snap and stretch fits, studs and lugs	Cements, solvents, cleaning equipment, clamps and jigs, other components
MACHINING AND FINISHING	Trimming or forming of plastics by use of tools subsequent to or in place of molding	Drilling, sawing, turning, milling, shaping, threading, tapping, crimping, stamping, bending, polishing, degating	Usual hand or machine tools
COMBINATIONS OF ABOVE	Varies with application and plastic material	.....	See above

afforded, especially against scuffing in stacking parts, by molding a small rim or bead to the part as shown in Fig. 7d.

Hand brushing is generally confined to work requiring minute detail or when individual craftsmanship adds something to the value of the part. This becomes more of an art than a commercial process.

Lacquering is not limited to colored coatings for decoration alone. Properly compounded clear lacquers can be applied to resist abrasion, to improve light stability, to prevent chemical attack and to destaticize. Electrically conductive or resistant lacquers are applied to molded-in scales for a variety of electrical parts. Several classified military electronic components use this principle for quick production of electrical circuits. Condensers have been developed employing a high dielectric plastic, lacquered with a conductive coating on each side. Plastic artillery and bomb sights and other fire-control equipment can be made to glow in the dark when coated with a phosphorescent lacquer.

Other Decorative Techniques

Other decorative techniques include printing, hot stamping and application of decalcomania. These have utilitarian value for identification and increased legibility.

Printing on thermoplastics can be done with the conventional flat-bed or rotary presses and consists basically of applying ink to the molded parts. As with lacquer the chemical composition of the ink is important. It must adhere without crazing and must not bleed with any plasticizer that may be present.

Production rates and costs for printing on plastics compare favorably with printing on paper and cardboard, once devices are worked out for holding irregular shapes.

Rubber-stamping is a sub-classification of printing. The conventional type of hand stamp is used, and again the chemical composition of the ink to be employed is the most important consideration. Rubber stamping is used more for identification than for formal decoration.

Silk screening is a combination of lacquering and printing. It consists of forcing onto the work a fairly thick lacquer through a silk screen with a roller or squeegee. In the case of plastics the technique has been extended to curved and irregular as well as flat surfaces. Its main advantages are flexibility of operation and the relatively low cost of the silk screen stencil as compared with metal masks.

Inks must be specially compounded and kept viscous to avoid flowing under the screen and smearing the part. By careful manipulation and accurate register, multicolor work can be done. Adequate drying time

PREPARATION REQUIRED	PRESENT USES	TRENDS	REMARKS
Clean surface. May require annealing to minimize crazing	Decoration and increased functional uses of all sorts, protection, reclaim molding rejects	More colors and finer detail, industrial uses other than decoration	Most popular post-molding treatment
Clean surface	Decoration and functional use	Industrial uses other than decoration	.....
Clean surface	Decoration and functional use	Use may diminish as other methods become improved and more economical	.....
Clean surface, electroplating requires electrically conductive surface	Decoration and functional uses of all sorts, protection, reclaim molding rejects	Finer detail, improved adhesion, industrial and military uses other than decoration	Second most popular post-molding treatment. Plasticizer vapor pressure may cause problems
None	Preparation for decoration or metallizing, avoids need for dusting item on sale or in service	Finding increased application in large moldings and industrial parts	Pertains mainly to styrene and acrylic. Material suppliers are engaged in research to produce self-destaticizing materials
None	Reduce strain and increase life in housewares, battery cases, industrial parts, military items	Increasing importance in industrial and military items where strain detracts from basic plastic properties; useful in larger moldings which must be decorated	Applicable chiefly to styrene and acrylic; other thermoplastics are less rigid and/or plasticized so strains equalize better. Preplasticizing injection presses may lessen need because of reduced inherent strain resulting from lower molding temperatures and pressures
Suitable preparation of other components	Varied	Improved tool-making and molding techniques, larger presses lessening importance in production runs	Conventional equipment may be employed
None	Varied	Ditto	Conventional tools may be used. Basic requirement is to machine slowly so that generated heat may be dissipated to avoid distortion of thermoplastic materials
See above	Varied	.....	.....

must be allowed between colors.

Hot stamping consists of imprinting a thin metal foil into the surface of a plastic item using a heated die.

This technique is used to print numerals and letters on plastic articles such as radio cabinets, Fig. 4, rulers and drawing instruments. Its advantages are:

1. Ease of decorating irregular as well as plane surfaces.

2. Use of one operation for both embossing and inking.

3. No letters or decorations need be made in the mold.

4. Economy of operation.

The foil can be any of a variety of colors and can be either shiny or dull. Multicolored work is possible if accurate register is attained through the use of a centering and holding jig. The work can be done in a hand-operated, semi-automatic or fully automatic press.

Curved or irregular surfaces may be hot stamped by cutting the die on the proper radius. Die temperature, pressure and time of application must be controlled to get the desired effect with the stamping. Since metal foil is used, this method may also be employed for applying conductive circuits to a plastic chassis.

Large automatic equipment for hot stamping requires a greater initial investment than silk screening equipment. However this is justified on long runs because of its faster rate of production.

The last major decoration technique is the application of decalcomanias. These are designs or inscriptions printed on separate sheets of paper or thin plastic. Whereas the other methods depend upon chemical or thermal attack, decals require only mechanical adhesion to the surface. Decals can be further protected by a top coating of clear lacquer.

The advantages of decalcomania application are economy, flexibility, and utilization of the highly-developed sheet printing techniques. Major industrial applications are for attaching manufacturers' identification or directions for operation and care of a product.

Metallizing of Plastics

Metallizing, or plating, enables the plastic manufacturer to coat his product, either wholly or in part, with a thin film of metal. Advantages include protection from scratching, resistance to chemicals or light and the reclamation of some rejected castings. In addition, parts can be made that combine the light weight and low cost of plastic with the lustre and surface hardness of metal. For electrical applications, the metallic film built up by plating is superior to conductive lacquers. Most of the usual metals and alloys can be plated.

There are four major methods for plating plastics: electroplating, spray

plating, vacuum metallizing, and sputtering. Electroplating requires that the plastic be rendered conductive, while the other three methods require a surface treatment that will produce proper adherence of the plating.

A conductive surface may be achieved by the application of lacquers or waxes which contain a suitable conductor, such as powdered graphite or metal. Another method is to react chemical solutions on the surface under controlled conditions to produce a conductive film. An aqueous solution of silver nitrate reduced with Rochelle salt, formaldehyde, or cane sugar solution, is the most popular and inexpensive. This technique is similar to the process for silvering glass.

Brush or spray application of conductive silver paint is also effective as a pretreatment of plastic parts to be electroplated.

Electroplating is the most inexpensive type of metallizing procedure to set up. The procedure closely follows the electroplating of metals, once the plastic has been made conductive. The object to be plated is attached to the cathode and immersed in a bath which has a bar of the metal to be plated as its anode. Both electrodes are submerged in a solution of the proper concentration of a salt of the same metal. Current flows from the positive to negative pole, carrying metallic ions to the plastic item, where they plate out at the same rate at which the cathode goes into solution. A major factor to be considered in the liquid electroplating process for plastics is their low specific gravity. Most are very close to or less than that of the plating solution. Devices must therefore be provided for holding the plastic castings under the surface. This may be done by rigid wire, sinkers, or other convenient devices. Occasionally, to minimize handling, an entire plastic shot is plated, then the parts are clipped from the runners.

Current densities and times must be carefully controlled, as adhesion of the metallic coat is dependent upon these items.

Spraying is another method of metallizing thermoplastics. It is used as a preliminary coating to make parts conductive prior to electroplating, or as a finish coat. Spray guns are

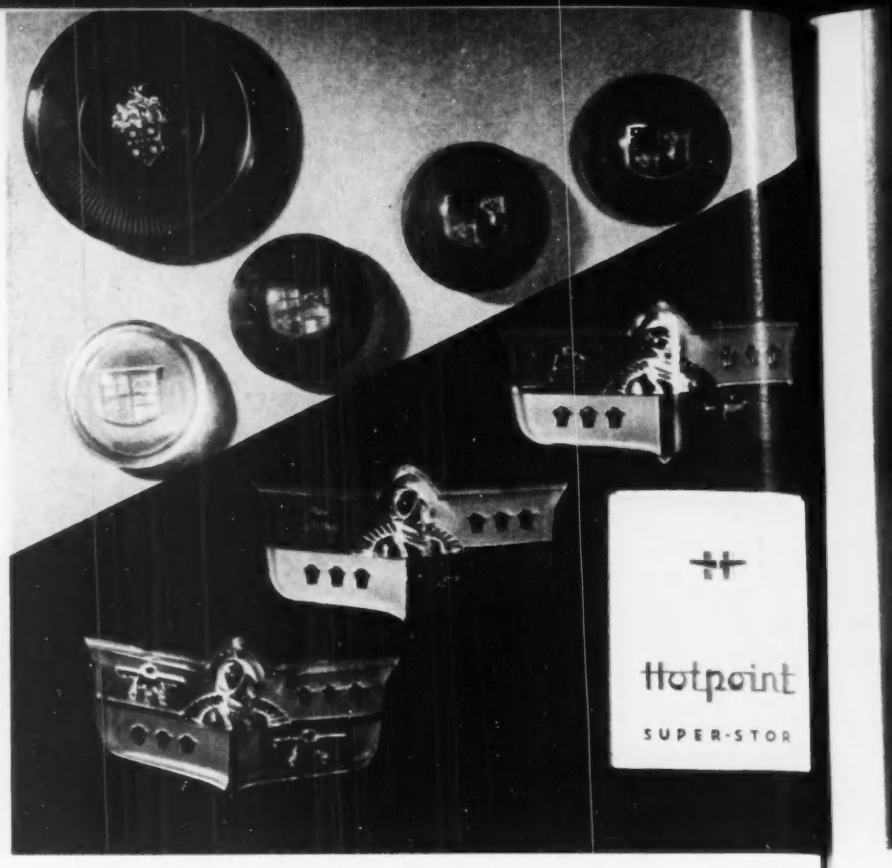


Fig. 5—Metallizing on plastics produces eye appealing effects as shown on the above parts. The horn buttons and auto emblems shown above were metallized on the back and lacquered.

positioned so that solutions of a soluble salt of the metal to be plated and a reducing agent strike the object and react simultaneously. For fine work, items spray-plated by this method are usually covered with a coat of lacquer to protect the gloss and finish of the thin metallic coating.

The Schori method of spraying consists of atomizing a metal ribbon in an oxy-acetylene flame with immediate condensation on a plastic object directly behind the spray. Because of the high temperature required to keep the minute droplets of metal in the molten state, the method is not too popular for thermoplastics, which may soften when the hot metal strikes.

Vacuum Metallizing is the most popular means for metallizing plastics. Although the initial investment for such vacuum equipment is high, it gives the highest gloss and most precise work, and is rapidly gaining popularity with plastic decorators.

The metals used in this process include silver, gold, gold alloy, aluminum and its alloys, antimony, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, tin and zinc.

Vacuum metallizing does not require a conductive coat, but the surface to be plated should be cleaned and prepared for good metal adhesion. Plastic items are placed in the vacuum vessel, and surrounding metallic resistance elements are loaded with small links of the metal to be plated. The system is evacuated and electricity is caused to flow through the resistance elements. They heat up rapidly and volatilize the metal links at a much lower temperature than normal because of the high vacuum. This metallic vapor condenses on the plastic parts, resulting in a very even, glossy coating.

By this method, a pound of aluminum can be used to cover as much as 25,000 square feet of plastic, and consistent coatings of as little as 0.000003" have been applied. Vacuums on the order of 0.001 millimeters of mercury or better are advised.

Cathode sputtering is a variation of vacuum metallizing, in which the plating metal is made the cathode and the object to be plated is placed on or near the anode. Under the influence of approximately 2,000 volts at 1 to 0.01 millimeters of mercury, the cathode metal evaporates and imme-

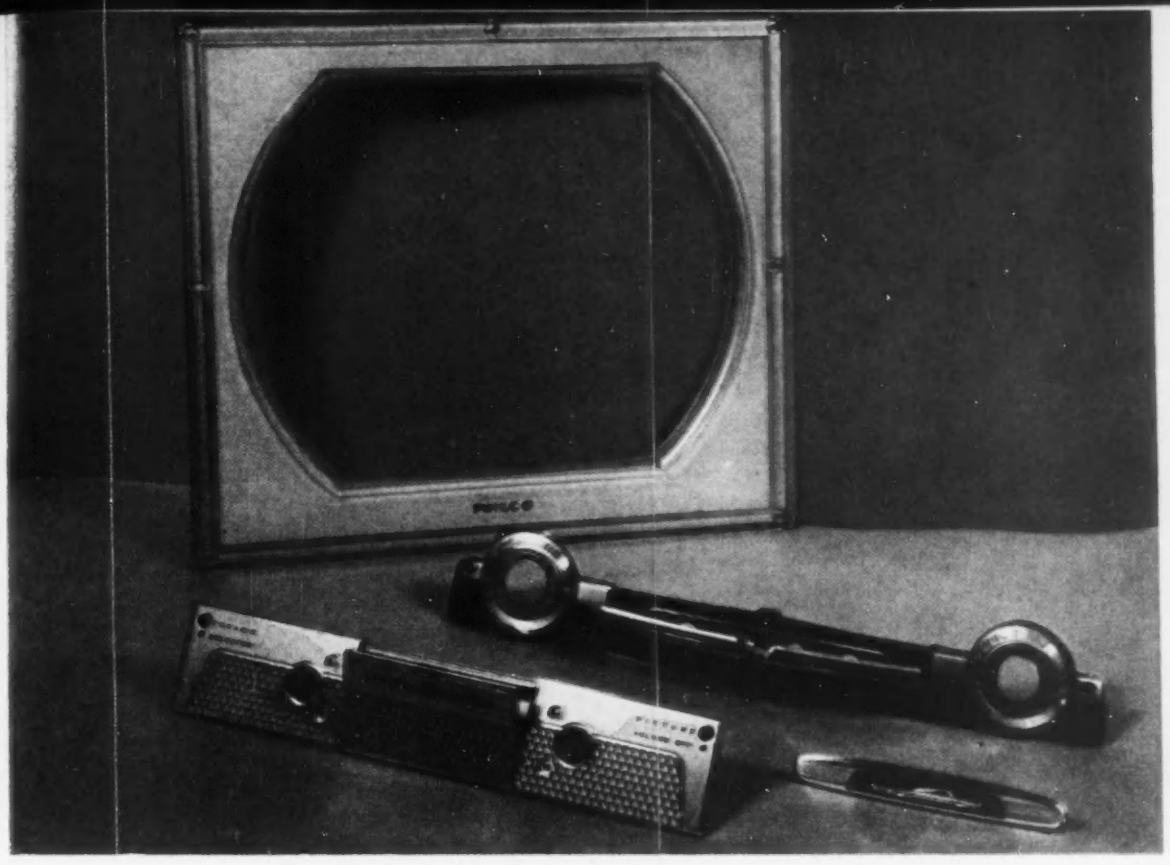


Fig. 6—Spray lacquering and vacuum metallizing have been applied to the above plastic parts to produce a metallic effect. The combination of this technique with other post-molding treatments such as printing results in good color contrast and other advantages.

diately condenses in the anode area. Cathode sputtering requires a smaller initial investment and less evacuation of the vessel. However, it results in a less glossy coat because of the presence of more air to cause oxidation. Aluminum alloys, silver and gold are the metals commonly used.

Metallizing Variations and Precautions

Multi-color work may be achieved through the use of a series of stencils and successive metal applications, usually on the reverse side to create a three-dimensional effect and to avoid abrasion or rapid tarnishing of the coatings in service. The technique may be combined with similar spray lacquering steps. This forms the basis for many insignia and medallions. Acrylic is generally used because of its clarity and excellent weatherability, although the use of styrene is making advances for indoor applications.

To inhibit oxidation of the metallic coatings, a coat of clear lacquer is often applied over the parts after plating. Colored lacquers can also be used to give deeper shade effects or to minimize the appearance of scratches which may occur in service.

Vapor pressure of some plasticizers may pose problems in attaining sufficient vacuum. In such cases, a sealer coat of phenolic varnish will be of assistance.

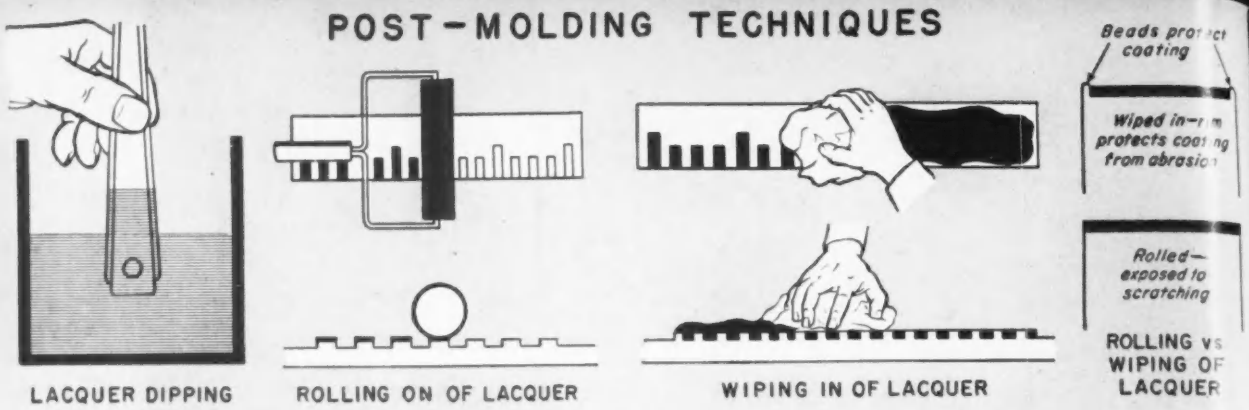
Small items such as buttons are best plated in a tumbling barrel by the wet process. The barrel acts as the negative pole, with a coaxial bar of the metal to be plated as the positive pole. The entire system rotates in a solution of the same metal. The small objects, which have been made conductive, intermittently strike the barrel walls and receive their metallic coating through electrolysis.

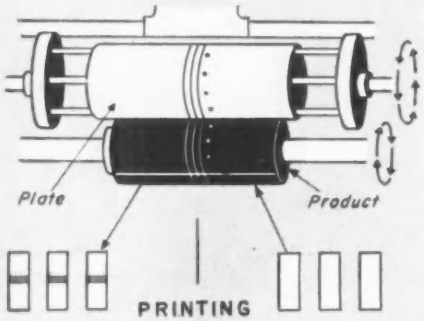
Manipulative problems sometimes occur with both lacquering and metallizing. One common solution is to decorate or plate the entire molding shot, including sprue and runners. This affords a means of gripping or rotating the parts to be treated without the necessity of "touching up" parts due to excessive handling or masking by the clamping device. Another problem frequently associated with either lacquering or metallizing is that of poor stencil fit. The cause of this is usually non-uniformity of the plastic moldings because of generally inconsistent shrinkage from cavity to cavity or from run to run. Shrinkage can be controlled accurately by consistent molding conditions. Occasionally, separate masks for each cavity are advisable rather than a retooling of a troublesome cavity in order to insure equal dimensions throughout. Various thermoplastics also exhibit greatly different mold shrinkages, which means that specially fitted masks should be provided for each plastic which might be run in a given die.

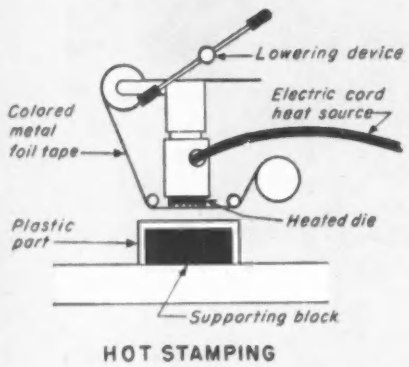
If the above techniques and precautions are followed, many metal-like items such as camera reflectors, mirrors, television and radio parts, and cutlery sets can be produced.

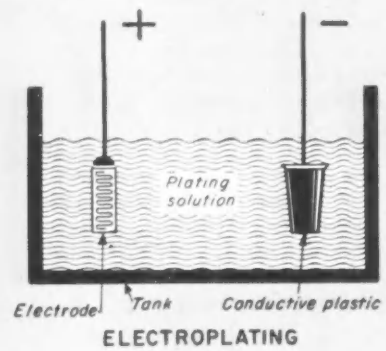
Destaticizing

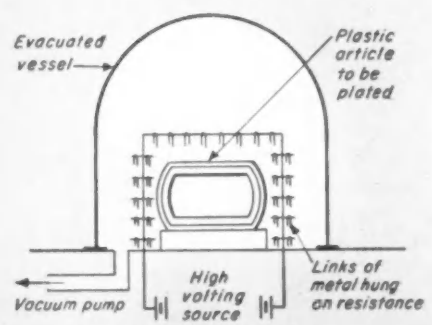
By virtue of their excellent electrical insulative properties, some thermoplastics accumulate a static electricity charge that attracts dust. This dust may be objectionable on the sales counter, in use, or prior to decorating. The rigid thermoplastics, particularly styrene and acrylic, are especially susceptible to this condition. Wiping to remove the dust is not effective since more static is generated











during handling or generation of any other type of mechanical friction, even as slight as passage of a part through the air. Destaticization, or the process of grounding out any static charge, thus becomes of prime importance. It is accomplished by coating the item with a more conductive film that prevents the accumulation of a charge that will attract airborne dust particles. For example, static generation is dependent upon decreased atmospheric humidity. As humidity increases, an infinitesmal coating of water builds up on the parts, acting as a conductor which carries away more of the charge.

Destaticization may be of two forms: permanent or semi-permanent. Semi-permanent destaticizers can be as simple as home-made solutions of the common synthetic detergents, glycerine, or other surface-active agents. They are applied by dipping, spraying, or brushing. The permanent forms are more chemically complex, usually lacquers or waxes which require spraying or buffing. Semi-permanents will wear or wash off quickly, while permanents are more durable.

A variety of commercial destaticizers are available, including various solutions or pure liquids, waxes, lacquers, and even radioactive materials which ionize the surrounding atmosphere so the air is made to act as its own conductor. Damp cloths may be used to remove static dust accumulations, but dry cloths will generate still more static and defeat their purpose. If the cloths are dampened with a detergent solution, a semi-permanent coating can be applied. Styrene housewares, for example, rarely pick up dust because of repeated washings while clock cases of the same material will become dusty if not suitably treated.

Other Post-Molding Treatments

Additional popular post-molding treatments include annealing of the rigid thermoplastics (notably acrylic and styrene), cementing or other means of assembly, and machining and finishing. These widely practiced techniques are not covered in the present article aside from general remarks in the table. They can of course be combined with any of the techniques explained above.

Several of the above after-treatments may easily be combined in a single operation for added economy and efficiency. In addition to the lacquering-metallizing and annealing-destaticizing already mentioned, many others are possible. Destaticization with permanent type waxes can be combined with buffing if a suitable buffing compound is chosen for the final polishing. Lacquer drying can be combined with air annealing in a drying oven, and radioactive destaticization simultaneously cleans parts for subsequent coating. Other combinations may be possible, depending upon the nature of the application and treatments employed.

Many of the post-molding treatments can be applied to the same finished part, for example the combination of lacquering and metallizing in automobile emblems, or annealing of a functional part prior to lacquering to minimize strain.

Any combination of these treatments is generally carried out along a conventional type of production line, utilizing belt or overhead conveyors and successive stations where the various operations take place. Inspection and packing can also be made a part of this continuous operation, particularly in new plants which can be constructed with such operations in mind.

PREBURNING is an effective way of weeding out unreliable electron tubes before installation in equipment. However, such aging is a costly and time-consuming addition to mass production techniques.

Increasing Tube Reliability In Industrial Circuits

D. G. KOCH

Tube Department, Radio Corporation of America, Harrison, N. J.

A SINGLE TUBE FAILURE in industrial electronic equipment may cost the equipment user hundreds of times the price of the tube. Tube failures often are caused by improper equipment design practices, particularly in cases where receiving-type tubes are used in industrial applications. Considerable progress has been made in programs aimed at increasing tube reliability in industrial circuits. Of particular importance are the ways in which the circuit designer may prolong the life of the tubes.

More industrial-type tubes are now available to equipment designers—tubes designed for specific industrial applications. Often, however, new circuit applications require particular tube characteristics which are as yet available only in receiving-type tubes. When these tubes are used, special care must be taken to insure reliability in operation. Receiving-type tubes are designed for use in home instruments, where it is unlikely that they will be subjected to extremes of temperature, to excessive shock and vibration, or to various other severe environmental or operating conditions encountered in industrial equipment.

In cases where it is necessary to use receiving-type tubes in industrial circuits, certain equipment design practices may be employed to increase reliability. Many such practices will be discussed in this article. All of them are important to the designer.

* *The author wishes to thank the people who so generously helped in the preparation of this paper for their constructive criticisms and for access to data gathered by them. In particular, the author would like to thank Mr. John Prayer for supplying the data for several of the curves used.*

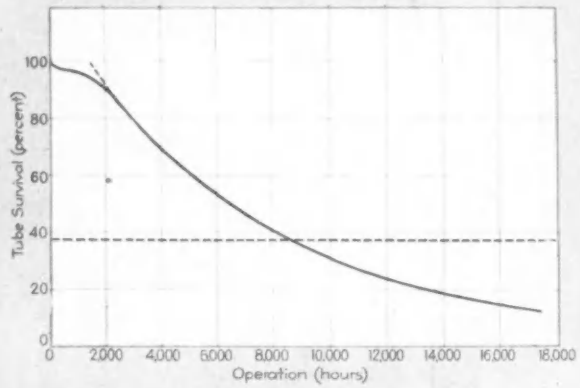


Fig. 1 — Survival curve of a filamentary triode-type tube. Average life is the point at which 37 percent of the tubes are still operative.

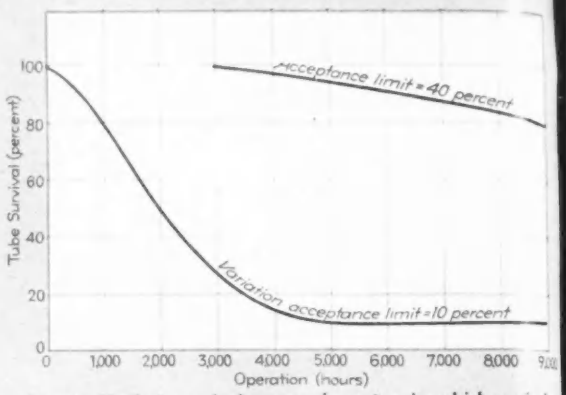


Fig. 2 — Typical survival curves for tubes in which variations of 10 and 40 percent in transconductance are allowable. Circuits should be designed for wider variations in tube characteristics.

Range of Tube Characteristics

Practical considerations, such as production speeds, testing problems and material costs, often fix the range of tube electronic characteristics at ±20 to 40 percent of design-center values. Even on special industrial types, where tighter controls and premium materials are economically feasible, characteristics may have tolerances of ±10 to 20 percent. These tolerances are caused largely by variations in dimensions of internal parts and in chemical properties of inner tube surfaces. The tolerances also reflect some unavoidable shifting of characteristics from one manufacturing lot to the next.

In a particular high-impedance triode, for example, typical manufacturing tolerances are in the order of ±1 percent on coated cathode diameter; ±1½ percent on grid diameter; and ±2 percent on plate diameter. A cumulative variation in characteristics of ±5 to 10 percent due solely to such tolerances on parts can exist in an appreciable number of these tubes.

Tube characteristics are also affected by such factors as degree of activation of the cathode over its length; contact potential between grid and cathode; and tendency toward secondary emission. And since complete stabilization of all tubes by pre-burning is not practical, wide variations in initial characteristics are normal. For example, because traces of metallic or gaseous contaminants on electrode surfaces affect contact potential, it is impractical to control the grid contact potential to limits closer than ±0.3 volts.

Because characteristics do vary from tube to tube, and also because many tube characteristics change during life, it is well to design circuits for operation over a wide range in tube characteristics. Life tests on a typical tube show that its average life is increased 2½ times if the acceptable change in transconductance is doubled. And the average life is increased 5 times if the acceptable change in plate current is doubled.

From the standpoint of reliability, however, the equipment designer is more interested in percent survival of tubes than in average tube life. For example, he would rather know that all tubes will last 1,000 hr than know that average life is 5,000 hr with a few tubes failing before 1,000 hr and a few lasting longer than 10,000 hours. Unfortunately, the latter case is closer to actual experience. In general, the survival of tubes in operation is typified by Fig. 1, in which the curve follows an exponential law after 2,500 hours.

The effect of wider tolerances for tube characteristics on survival is illustrated in Fig. 2. Percent survival vs hours of operation is plotted for maximum allowable transconductance changes of 10 and 40 percent, respectively. If the desired reliability criterion is survival of 80 percent of the tubes, it can be seen that a transconductance limit of 10 percent change yields 1,000 hr life, while a limit of 40 percent change yields 9,000 hr life. Often, tube life may be further extended by providing means of adjusting circuit conditions, at least initially.

Pre-Burning and Tube Selection

Tube failures may occur in significant number during the early hours of life. Many of these failures are caused by opened welds or shorted elements. Other early failures are caused by sudden shifts in tube characteristics to values outside acceptable limits. To improve tube reliability, many industrial users pre-burn tubes for 50 to 100 hr under conditions simulating intended applications to stabilize characteristics further and also to eliminate early mechanical failures. Tubes designed specifically for industrial service often receive a similar 50 hr stabilizing burn-in as part of the standard manufacturing processing. Preburning of all mass-produced tubes is, of course, impractical.

To get a desired range of tube characteristics an equipment designer sometimes is tempted to select, from available stocks, tubes having tolerances closer than tube manufacturers provide. If the quantity of tubes involved is sizable, however, this practice can be costly. Furthermore, there is no assurance that the yield of tubes with the desired range of characteristics will be maintained in future production. Such an arrangement also poses tube replacement problems for the equipment user.

In industrial service, successful operation of a circuit often depends on some tube characteristic for which there is no published information. In such cases, the tube manufacturer can advise the equipment designer as to how closely a given tube type does maintain the desired characteristic. The tube manufacturer may suggest another type in which the critical characteristic is controlled more closely.

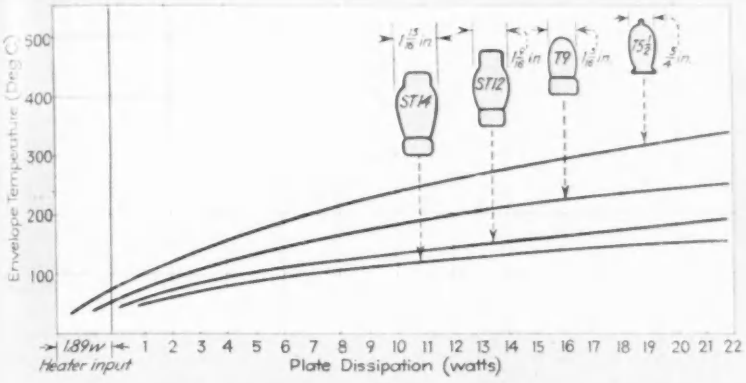


Fig. 3 — Envelope temperatures as a function of input power for various sizes of glass tubes. Excessive temperature can shorten the life of any tube and is a more critical problem in the smaller-envelope sizes.

Maximum Tube Ratings

Maximum tube ratings set by tube manufacturers are the limits within which tubes must be operated for satisfactory performance. Ratings for receiving-type tubes, in general, are not as conservative as those for industrial types. Therefore, when receiving-type tubes are used in industrial circuits where longer life is desired, maximum ratings must be re-evaluated.

When several maximum ratings are given it is not wise to assume that one rating (for example, plate voltage) may be exceeded, provided that a corresponding reduction is made in the other ratings. The first maximum rating reached should set the limits for all other conditions.

The operating frequency is another factor to be considered. When tubes are operated at high frequencies, the internal tube losses increase, reducing efficiency and, therefore, permissible maximum input. Dielectric losses in the glass stem between lead wires may increase sufficiently at high frequencies to raise the glass temperature and hasten electrolysis failure. Rectifiers operate at high temperatures and high inverse voltages and, therefore, are particularly susceptible to electrolysis. At high frequencies, dielectric losses in the glass envelope near points bombarded by stray electrons may increase sufficiently to overheat the glass, causing cracks or evolution of gas from the glass envelope. In all cases, therefore, the permissible tube dissipations for maximum reliability are lower for operation above some critical frequency.

Envelope Temperature

Tube life may often be extended by maintaining envelope temperatures at low values. This is especially important in power-output types because of their higher plate and heater dissipations. The temperature rise of the envelope may be limited by: (1) reduction of total tube dissipation; (2) provision for improved ventilation; and, (3) maintenance of low ambient temperatures. In general, the envelope temperature of small receiving-type power tubes should be kept below 175 C for increased reliability.

The tube envelope, as well as other glass and metal surfaces within the tube, holds by adsorption and absorption small amounts of gases. If released during tube operation, these gases cause poor performance. In receiving-tube processing, the degassing process includes heating of all parts to drive off gases, mechanical evacuation of the tube by high-vacuum pumps, and chemical cleanup of gases within the tube by gettering materials. All but minute quantities of adsorbed gas are removed from the glass envelope. The complete removal of adsorbed gas from the glass envelope would require hours of baking at temperatures of 250 to 300 C, which is impractical for high-volume receiving types. If, during subsequent tube operation, envelope temperatures equal or exceed those used on exhaust, some of the remaining adsorbed gases will be liberated. A limited amount of these gases can be absorbed by the gettering material, but excessive gas evolution results in minute traces of free gas in the tube.

The presence of free gas in a tube can be undesirable for a number of reasons. The gas molecules may become ionized due to collisions with electrons during tube conduction. These ionized molecules migrate to the negative electrodes in the tube. Those traveling to the control grid are equivalent to an electron flow from the grid and produce across any grid circuit resistance a voltage drop which tends to increase the flow of cathode current. In addition, if ions arriving at negative grids are sufficiently energized, they knock out electrons and cause reverse or secondary emission from the grids.

Gas ions arriving at the cathode may dislodge cathode coating material by bombardment. Furthermore, because the hot cathode has a great affinity for gas, ions arriving at the cathode combine with the free barium, so that emission is gradually reduced. Thus, envelope temperature is more critical for tubes having smaller cathode areas.

The envelope temperature is a function of the heat generated within the tube, the envelope size, and the ambient temperature. The relationship of envelope temperature to total power dissipation for tubes of various sizes operating in air of normal room temperature (approximately 30 C) is shown in Fig. 3. The temperature of the plate and screen electrodes of tubes results primarily from the conversion into heat of the energy of electrons arriving at these electrodes. Typical operating temperatures for the plate and screen electrodes of power pentodes are of the order of 400 to 450 C. Plate temperatures for triode types range from 300 to 400 C, depending upon the power input. Any increase above these temperatures results in envelope temperatures which are increasingly troublesome. In addition, the probability of release of residual gases from the parts is increased.

The ambient temperature can be controlled by good ventilation, using blowers if necessary. Reductions in envelope temperature have been obtained with miniature and subminiature tubes by the use of close-fitting metal jackets thermally connected to the chassis so that the chassis serves as a heat-radiating surface or by shields designed to cool the envelope with convection currents. When a solid bond to the chassis is not made, the use of conventional metal shields around tubes can raise envelope temperature as much as 50 C. To promote heat radiation, plated shields should be avoided and surfaces surrounding the tube unpolished.

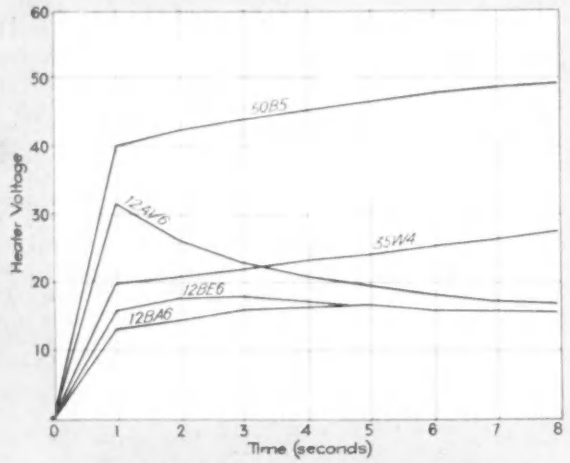


Fig. 4—Initial heater-voltage surges in series-string operation of five different receiving tubes. Type numbers of tubes are indicated on the curves.

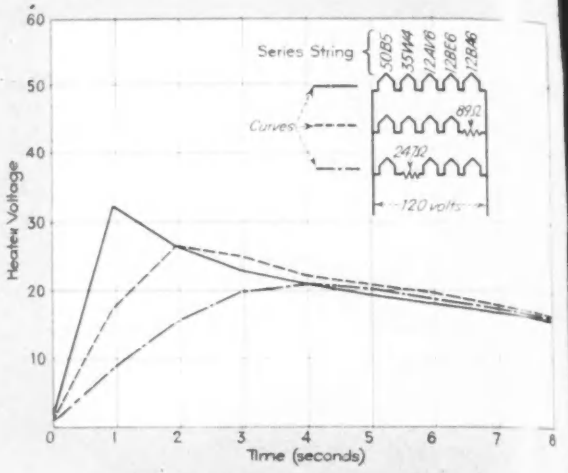


Fig. 5—Curves illustrating the effect of inserting resistance in series with a heater string. Legend at top right identifies the curves.

Cathode Temperature

For long life, oxide-coated cathodes must be operated at recommended temperatures. For most tube types, ±5 percent of rated value is the maximum allowable heater-voltage variation for long life. Because industrial electronic equipment often must operate with varying line voltages, regulation of heater voltage should be considered.

At cathode temperatures above recommended values, evaporation of free barium from the cathode surface is accelerated, and cathode emission decreases with time to values insufficient for certain applications. This effect is most serious in the case of power-output and rectifier types, where normal cathode temperature is relatively high to provide the abundant emission required for satisfactory performance.

Elevated cathode temperatures cause the deposition of vaporized emitter materials on tube electrodes such as grids or plates, or on surfaces of glass or mica insulators. Such deposits increase the tendency of electrodes to become emitters during operation, and may cause undesirable reverse currents to flow. If such currents flow in a grid circuit containing high resistance, the voltage drop produced often upsets normal functioning of the tube. Higher cathode temperatures in turn cause higher operating temperatures of other electrodes and increase the possibility of reverse emission. Deposits of emitter material on insulating surfaces may give rise to noise or faulty insulation between electrodes.

On the other hand, when the cathode is operated below recommended temperature, emission decreases and may go below the safe limit required to maintain desired tube characteristics over a long period of operation, especially in applications requiring high peak current or power. A phenomenon known as sparking may result from the emission becoming confined to localized spots of high current density in the cathode.

A more common effect of low-temperature operation is poisoning of the cathode because of gas absorption. The lower the cathode temperature, the more readily it absorbs gas. Very small amounts of oxygen or carbon monoxide poison a cathode (i.e., drastically reduce its emission).

If voltages are applied to other electrodes while the cathode is below operating temperature, ion bombardment of the cathode may cause permanent damage to the cathode coating. After the cathode has reached operating temperature, the electron cloud surrounding it neutralizes ions arriving there and prevents damage to the coating. Thus, where equipment is subject to many cold starts, the life may be extended by applying electrode voltages only after a cathode warm-up.

Grid Resistance

In the present stage of the tube-manufacturing art, grid currents of the magnitude of one microampere may be present in receiving-type tubes. The designer, however, can frequently compensate for this grid current by using the smallest practicable value of grid resistance. This precaution is necessary because excessive grid resistance may produce "run-away" tubes. Whatever negative grid current exists flows through the grid resistor, causing a shift in bias that is proportional to the value of resistance. For instance, a negative grid current of one microampere through a grid resistance of one megohm decreases the negative bias by one volt. The bias shift tends to increase plate current.

A larger plate current increases ionization collisions and thus ion current to the grid, which, therefore, swings even less negative. If grid resistance is too large, this effect may be cumulative, so that plate current reaches destructive values.

Negative grid currents may result from ionization of residual gases, grid emission, or leakage across insulation inside the tube or externally across the tube base. An additional reason for reducing grid resistance is that high grid resistance increases the susceptibility of the circuit to the pick-up of undesired voltages. Transformer coupling between stages of amplifiers is often advantageous for obtaining low d-c grid resistance. Usually, the grid resistance should be kept under 200,000 ohms for power-output types and under 2 megohms for all other types. Cathode-resistor bias, by virtue of its effective degeneration, may be used to minimize the harmful effects of larger grid resistances.

Operation of Heaters

When full heater voltage is applied to a cold heater, the heater assembly is subjected to thermal shocks and strains caused by expansion and unequal heating of the heater wire. Expansion causes physical abrasion against the cathode, especially near the cathode ends. During warm-up, strain is also placed on the heater welds at the stem leads. A high rate of on-off switching may cause heater failure due to fatigue.

In many installations it is possible to maintain continuous operation, and thus to reduce the frequency of switching. Or, by applying or removing heater voltage gradually when the equipment is turned on or off, heater failures can be virtually eliminated.

In general, low-voltage (6.3 v) and high-current (300 milliamp or more) heaters because of their heavier wire are better than high-voltage or low-current heaters for reliability.

Under certain conditions, series-string operation may represent very severe service. For purposes of illustration, a conventional receiver uses types 12BA6, 12BE6, 12AV6, 50B5, and 35W4 with all heaters connected in series. If the heaters are all at room temperature, then at the instant voltage is applied to the heaters a current of the order of 6.5 times the "hot" current flows through the heater string. The 12 v heaters have lower thermal inertia, and so they show a more rapid increase in heater resistance and temperature than do the 50B5 and 35W4. As a result, initially most of the line voltage appears across the three 12 v heaters.

The curves of Fig. 4 show that within the first second after voltage is applied to the heater string, the voltage across the 12AV6 rises to 31.5 volts, while the voltage on the 35W4 and the 50B5 remains well below rated values for five seconds or more. The effect on the 12AV6 heater voltage of replacing part of the series string with a resistor is shown in Fig. 5. Replacing the 12BA6 with an 89-ohm resistor reduces the peak heater voltage on the 12AV6 by 20 percent. Replacing the 35W4 with a 247-ohm resistor reduces the peak voltage by approximately 30 percent to 21 volts. In addition, the rate of rise of heater voltage is decreased as the series resistance is increased, further reducing thermal shock to the heater.

The effects of series-string operation are aggravated by the fact that the temperature is not uniform along the length of the heater, but may be concentrated in small sectors such as the uncoated sections of wire near the stem lead welds. On tube types having a cathode of small mass and low thermal inertia, the heater temperature may rise to a value that will cause sintering of the heater insulation.

If series-string operation is unavoidable for particular applications, the following will improve reliability.

1. Use tubes with less than 300 milliamp heater current.

2. The total heater voltage of slow-heating types should be less than half the total string voltage. Limit the surge voltage across any heater to less than twice the rated value.

3. A resistor should be used in series with the heater string to make up at least 15 percent of the load.

4. Series-parallel combinations should be avoided. A resistance in parallel with part of the heater string increases voltage surges. For instance, if a resistor is used across a 150-milliamp heater to include it in a 300-milliamp string, the 150-milliamp heater passes a greater current initially than it would in a 150-milliamp string. If possible, high-current heaters should be used in one string and low-current heaters in another.

Standby and Cutoff Operation

During vacuum-tube operation, a layer known as the interface gradually forms between the cathode base metal and the cathode coating. If, however, the tube operates for long periods of time while biased beyond cutoff, this interface layer may take on characteristics equivalent to those of a cathode resistor of a few hundred ohms shunted by a capacitance of 0.01 microfarad, resulting in faulty circuit performance. In some cases, cutoff life is as little as 5 percent of average conduction life. However, if the minimum cathode current can be maintained greater than 0.5—1.0 milliamp, harmful effects of the interface layer can usually be avoided satisfactorily.

Some cathodes exhibit this interface characteristic and others do not, depending to a large degree upon the composition of the cathode base metal. Because receiving-type tubes are designed for the requirements of radio service, where cutoff operation is not a problem, these types may not have a satisfactory "cutoff-life" characteristic. Several industrial tube types are made with relatively "inactive" cathodes to improve performance in applications where cutoff life is important.

Standby or heater-only operation produces effects similar to those of cutoff operation, and should be avoided where possible or at least restricted to short periods of time. If standby operation is required, tube life may be extended, as demonstrated in Fig. 6, by operating the heater at reduced voltage during standby.

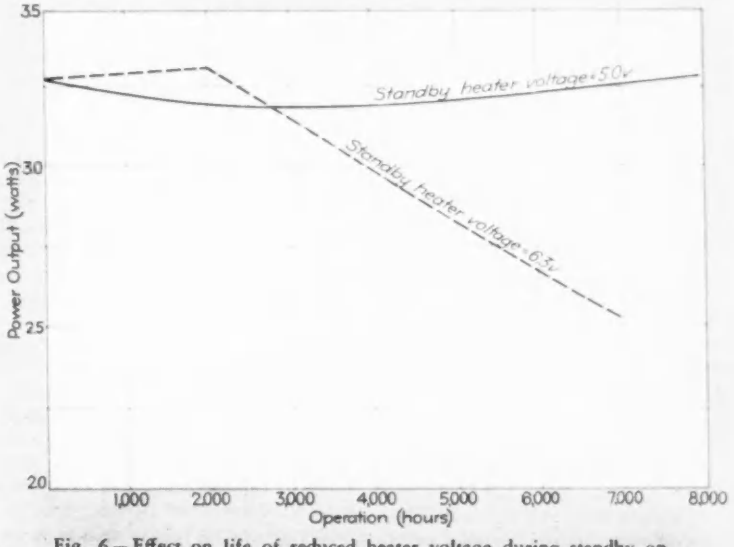


Fig. 6—Effect on life of reduced heater voltage during standby operation of a typical receiving tube. If such usage is needed, tube life can be extended by applying reduced heater voltage during standby.

Shock and Vibration

Conditions of shock and vibration may cause a tube to fail by shifting its characteristics, by causing a short between elements, or by causing an open circuit in one of the elements.

Receiving tubes are generally not designed or tested to withstand unusual shock or vibration. Tubes designed for industrial service, however, incorporate features that make them less suspectible to shock and vibration failure. There is a limit, nevertheless, to how far tube design can accommodate shock and vibration and still provide desired electrical characteristics. Beyond this point shock and vibration must be reduced or eliminated by suitable shock mounting of equipment and tube sockets. Much can be done even with standard tubes by proper shock mounting. All electrical connections to a shock-mounted socket should be flexible or the purpose of the shock mounting may be defeated. If vibrations are air-borne, damping of the tube with lead may be required.

Noise and Hum Output

Although most industrial applications do not require critical limitations on noise or hum output, several methods may be used to reduce tube noise or hum where necessary. Electromagnetic and electrostatic fields set up within the tube envelope by the heater may produce a hum voltage in the tube output circuit. Such hum can be nullified by a hum-balancing potentiometer connected across the heaters with the center-tap connected to ground. Often sufficient balance is obtained merely by connecting the heater transformer center-tap to ground.

Hum output may also be caused by leakage through the heater insulation material. As shown in Fig. 7, the resistance of the insulation varies with d-c bias, the lowest value of resistance occurring within a volt or two of zero bias.

When a heater-cathode type tube is operated with cathode-resistor bias, it is possible that leakage through the insulation between the a-c operated heater and the cathode will be sufficient to develop voltage across the cathode resistor. The undesirable effects of such a voltage can be avoided if the cathode resistor is bypassed with a capacitor of 25 microfarads or more. If bypassing is not possible, a d-c bias of 5-60 v positive or negative applied between heater and cathode shifts the operating point to the relatively flat portion of the curve, as shown in Fig. 7, and the hum current is reduced considerably.

The undesirable characteristic known as microphonism must also be considered in high-gain amplifier design. A tube is microphonic when, with no input signal, it gives rise to an output voltage while it is being lightly tapped with a felt mallet. Microphonism is a resonant effect. The microphonic output is the result of resonant vibration of some internal tube structure. If the microphonic tube is acoustically coupled to the audio output of the amplifier of which it is part, sustained oscillation may result. Tube manufacturers have gone to extensive measures to control microphonic characteristics of critical tube types. But in spite of all precautions, some microphonic tubes undoubtedly will appear good during testing and pass inspection.

Shock-mounting the socket will isolate the tube from the chassis as a source of vibration or shock. If the acoustic feedback is through the air, other components may be placed in the air path between the acoustic output and the tube, and the sound reproducer may be moved farther away. Where space is at a premium, the tube vibration may be damped by such means as weighting the critical tube with a cylinder of lead. Noises known as thumps, clicks or pops may be detected by testing, and tubes exhibiting these noises can be removed from critical stages and used in the less critical later stages.

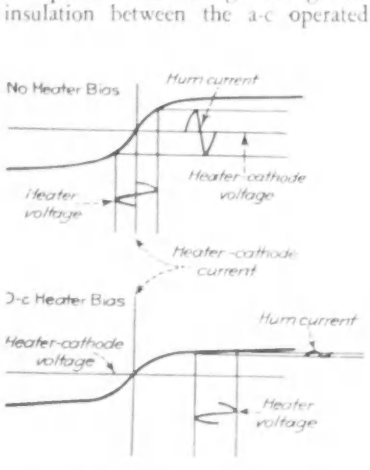


Fig. 7—Resistance characteristics of heater insulation material, showing effect of d-c heater bias on hum. Leakage of current through the heater insulation can have undesirable effect on operation.

Socket Design

Industrial electronic equipment is often expected to operate at elevated temperatures, in corrosive, humid, or dusty atmospheres, and under conditions of vibration. Good tube-socket design can improve circuit performance and reliability in such cases.

Tube sockets should be made of the best dielectric materials. The metal parts should be plated with corrosion-resistant material such as nickel. The socket contacts should grip the tube pins firmly without putting a physical strain on the rest of the tube structure, such as the glass stem of miniatures. In some cases, the use of shields that lock to the base of the tube is required to keep the tubes secure in the sockets.

The use of heavy wiring for connections to the tube socket terminals promotes longer life in some cases by reducing the temperature of leads within the tubes. If leads run too hot, rectifiers will have shorter life due to electrolysis of the glass between the leads. In certain tubes such as power-output tubes, where grid temperatures tend to run high, heavier electrical connections are used between the grid and the stem leads to reduce the grid temperature and to prevent grid emission. In such cases, good thermal conductivity of the socket contacts and of the wiring to the grid may help.

Tube Maintenance

The designer of industrial electronic equipment should consider the problem of maintenance, including availability of replacement tubes, frequency of tube maintenance routines, and the manner of testing tubes. Ease of maintenance is often a key to reliable operation.

A common practice in industry is the replacement of tubes on a periodic schedule regardless of their condition. It is doubtful that this method insures any greater reliability, because tube failures in operation follow a logarithmic pattern (Fig. 1), with some tubes failing in a few hours and others lasting several thousands of hours. The automatic replacement schedule neither

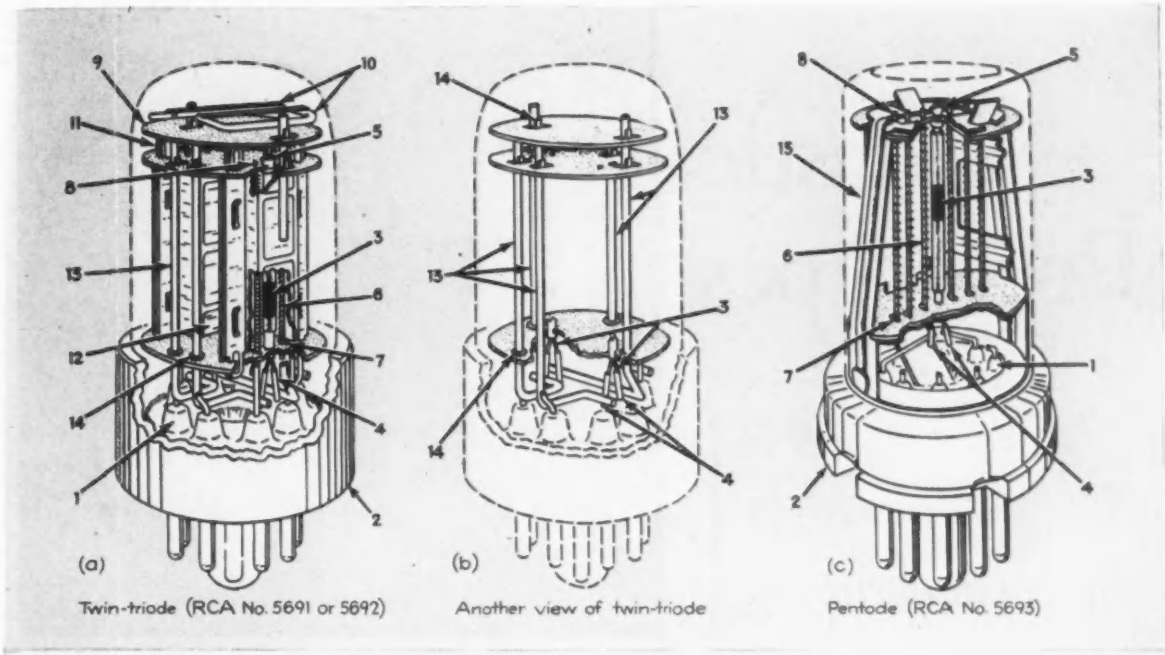


Fig. 8—Design Features of Industrial-Type Tubes

1. A button stem is used so that leakage between stem leads is minimized.
2. Base material is non-hygroscopic to maintain good insulation between pins under adverse humidity conditions.
3. Heaters are made of pure tungsten for high mechanical strength.
4. Heaters are enclosed in sleeves to insure a good mechanical and electrical bond between heater and heater leads.
5. Cathode sleeves are locked to mica insulators to restrict movement under vibration and shock.
6. Grids are plated to minimize variations in contact potential from tube to tube, initially and in individual tubes during life.
7. Short cross members are welded to grid side rods to prevent vertical movement of the side rods.
8. Grid side rods fit tightly into mica insulators.
9. An extra mica insulator prevents getter material from creating leakage paths across insulators.
10. Two getters are used to insure good vacuum and long life.
11. Plates are rigidly held in mica insulators by ears wedged against the insulators.
12. Completely enclosed design of plates minimizes electron coupling between units.
13. Elements are held together in a secure assembly by five supporting rods.
14. Twelve reinforcing eyelets provide a firm bond between mica insulators and five supporting rods.
15. Integral "A-Frame" is used for strength.

eliminates early failures nor obtains the benefit of the better tubes having long useful life.

In general, tube failures may be classified as sudden or gradual. The sudden failures are due to such causes as shorts between elements and open elements, and usually occur early in life. They are unpredictable, but may often be reduced by a pre-burning operation before actual use in equipment.

Most tube failures, however, are due to the gradual decrease in emission or transconductance, and can be detected before performance is below minimum requirements by periodic tube checks. Preferably these checks should consist of measurement of tube performance in actual operating equipment. To facilitate such tests, the designer should provide easy access to tube sockets or special testing connections brought out to convenient terminals. The tests should indicate the margin of safety remaining in critical operating characteristics.

A refinement of this technique is the "Marginal Checking" system in use on at least one large electronic computer. This system consists of changing operating conditions (such as supply voltages, signal levels, etc.) in such a manner that the computer will misperform if tubes of marginal performance are present. Additional means are provided for making such checks on small sections of the computer to localize a failure rapidly.

Industrial Tube Designs

Circuit reliability can best be obtained by using the available industrial-type tubes whenever possible. Examples of such tubes are the RCA-5691, 5692, and 5693. As illustrated in Fig. 8, many special features have been incorporated in the industrial types to insure reliability in specific industrial applications.

Long life is also built into these special tubes as the result of: (1) designing the cathode to operate at relatively low temperatures; (2) maintaining exacting control during processing to prevent deposit of cathode materials on other electrodes; (3) using pure-tungsten heaters provided with sleeves to give long heater life with frequent "on-off" switching; (4) inspecting each assembly for adherence to rigorous specifications; (5) rating the tubes conservatively; (6) using inactive cathode base metal for good cutoff life.

All industrial tubes are given a stabilizing 48 hr aging before testing. Tests are made for more characteristics and to tighter limits than on receiving types. For example, the published characteristics state that the maximum value of reverse grid current is 0.2 microamp for type 5691 and 5692 and 0.1 microampere for type 5693.

These features combine to make a tube having a minimum life of 10,000 hr, exceptionally uniform and stable characteristics, and resistance to shock and vibration.

Plastic Prototypes

bridge gap between design and manufacturing

New techniques of transferring a drawing to a plastic model are enabling engineers at the Ford Motor Company to better visualize preliminary designs and make changes prior to tooling. Inexpensive and quickly molded, such models have tremendous potential for all types of component parts and body assemblies.

SHEET-PLASTIC PROTOTYPE of complex stamped and welded assembly provides engineers and manufacturing staff with a 3-dimensional visual aid for evaluating a design with respect to function, appearance, cost, and practicality for manufacturing. Prototype is of truck section.

PRODUCT DESIGNERS and manufacturing men can afford to experiment with a number of proposals before the design is frozen. Thus, instead of a product incorporating after-thought engineering changes that are absolutely essential, the product design actually evolves much further.

BLUEPRINTS, the engineer's language, often are so involved that their meaning and implication cannot be fully understood by those who must plan and supervise manufacturing. Third-angle projection is inherently a poor form of expression when detailing a complicated joint or a complex-contoured item. In fact, the designer occasionally may be unable to visualize where a structure is weak or where a poor fitup will ensue after parts are made and assembled.

Perspective illustrations are helpful in clarifying the features of a product design or important sub-assembly. But there is one further step that has even greater advantage—the plastic scale prototype—since it permits better visualization and allows both engineering and production personnel to study problems that may arise in manufacturing, assembly, and shipping.

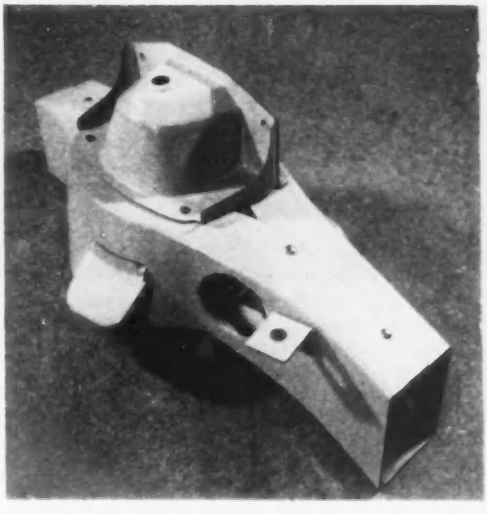
Solid plastic prototypes, or "models" are not new. They were the logical outgrowth of work done in the last war to quickly make cast form blocks, drop hammer dies, and fixtures with casting resins. But the scale prototype made of formed sheet plastic is new.

Both kinds can be made for study in a few hours or few days at most after the designer has laid down the form, shape and approximate dimensions of a product.

Time saving plus more clarity was the objective sought by the Ford Motor Company, when it set out to develop the technique for making sheet-plastic models. There are many complicated stamped jointures in an automobile. In normal practice blueprints did not reach the manufacturing staff until after this procedure: (1) development and acceptance of a full-scale clay model of the automobile, (2) drafting of a full-scale body draft from dimensions taken from the clay model, (3) design and detailing of subassemblies from the body draft. Following all this, stacks

ONE PROCESS for making plastic prototypes in a few hours or days involves: (1) a modeling a clay form to the desired scale, as shown, (2) setting the form into an inclosure and pouring in cold-forming rubber to produce mold at center, (3) casting a resin into the mold to make a plastic forming buck, lower left, and (4) forming sheet plastic over the forming buck, to produce articles like the experimental hood. Models can be made in hours—or at most a day or two—after initial design.

DIMENSIONALLY ACCURATE and realistic automobile frame made ¼th size. Left foreground shows 18 wood forming bucks used to make plastic replicas of frame parts. Prototype for convertible frame is at right, and model maker is completing the frame for 2-dr and 4-dr sedan.

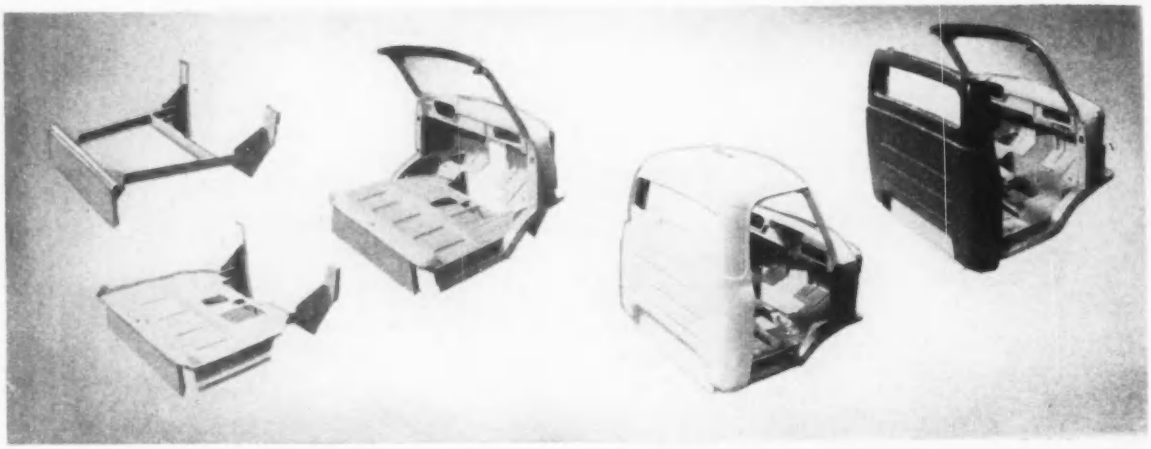


LIGHTNESS and lack of sharp corners make plastic prototypes ideal for evaluation studies. Product designers and key tooling personnel can take the assembly apart readily to study problems of each part.

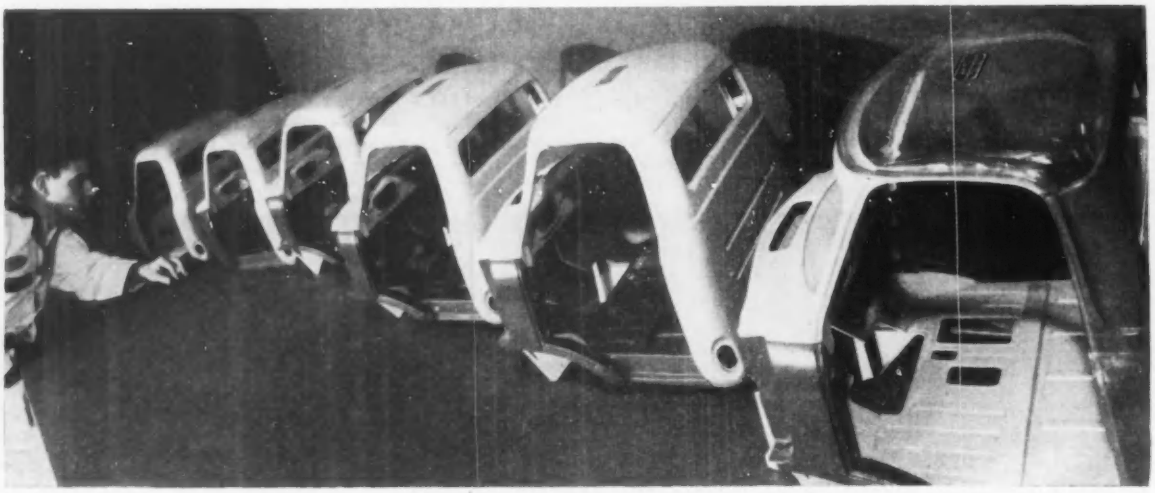
of blueprints were turned over to the manufacturing staff, plus descriptions, sketches, clay forms and photographs.

Analysis of such a mass of material by key manufacturing personnel consumed too much valuable time. The possibility existed that future problems might not be fully foreseen. Only a few men could study the material at a time. They might fail to see the features of design in the manner intended by the product engineer. They might also fail to see manufacturing problems in the same way. Anyone looking at a prototype will appreciate how much better one "sees" the features of the design from the model, as compared to the blueprint.

Ford's use of models to coordinate design and manufacturing study was put into force with the 1952 programs for the Ford, Mercury and Lincoln automobiles. More than 50 projects were studied in the plastic prototype form. Instead of waiting for detailed part and sub-assembly drawings, the designer produced an outline with only key dimensions noted, as taken from the body draft. These dimensions were accurate to within 0.015 in. Outline drawings



COMPLICATED STRUCTURES are readily produced with sheet plastic. These five stages show sequence of assembly of a prototype for an experimental truck cab. The time to turn out a better design can be telescoped from months into weeks. And with manufacturing studies proceeding at a parallel pace, the company able to work in this fashion should be able to exploit changing markets.



DUPLICATE PROTOTYPES are quickly produced so that all groups concerned may have one for study of various problems of manufacture, assembly, and shipping. Model at right has transparent roof so internal details at roof line can be seen. Frequently, changing a construction results in higher shipping or manufacturing costs, which are offset by reduced assembly cost.

were sent to the Model Shop operated by the Forward Product Illustration and Model Department of the Manufacturing Staff. Here six craftsmen skilled in making wood patterns, clay and plaster models, rubber molds, and similar arts converted the designer's sketches into 3-dimensional visual form.

Some complex assemblies were made available for study in less than a working day! Thus, 3 to 5 months ahead of detailed drawings, a conference of 6 to 20 designers, tooling experts, process and materials handling people, assembly supervisors, and shipping personnel could gather to discuss the design, each from his own point of view.

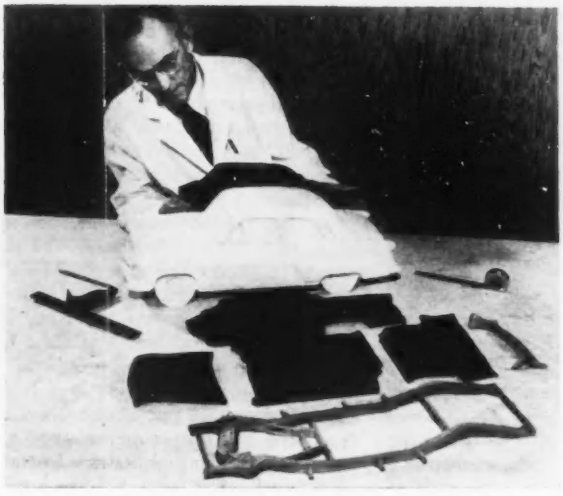
When engineering departments receive constructive criticism from the manufacturing staff early in a program, there is still time to make design revisions. Since detailing has not yet begun, the opportunity is still available to seek the optimum design for manufacturing.

In practice, the designer welcomes the chance to see his creation in the flesh, while there is still time to correct defects in structural strength, appearance and function. Often the prototype will show that poor fitup is bound to occur, that the sequence of assembly is complex, that joints do not properly overlap to provide enough weld space and rigidity, that the design lacks accessibility for spot-welding tips, that either the part cannot be stamped in one piece, as expected, or that a complex assembly of two or more parts can actually be simplified and drawn in one piece.

There is another reason why the product designer likes prototypes. Once the various aspects of the design have been decided to the satisfaction of all, he can go ahead with the final detailing without worrying about the flood of engineering changes otherwise likely to come from tool engineers. He will have the satisfaction of avoiding this extra effort, and of knowing that a better product can be introduced on schedule. Further, he will not share responsibility for manufacturing troubles that cannot be avoided during the model run.

Plastic prototypes cost very little as compared to handmade metal ones. A complicated jointure in steel might readily take three months to make and cost upwards of several thousand dollars. Then it would be useless, because the design would have advanced beyond that point. The

CAST-PLASTIC DUPLICATES of castings, forgings, extrusions and die-cast parts can be made for manufacturing and engineering studies. Duplicating process starts with a wood mock-up.



MAJOR SHIPPING ASSEMBLIES of the 1952 Ford were studied from ¼-scale plastic prototypes, to determine nesting, space economies, and handling as well as assembly details.

plastic prototype takes a few hours or a couple of days to make—can be easily duplicated—and seldom costs more than $100. The plastic can be reworked, patched, fastened together readily, painted or trimmed. Also, various parts of a sheet-plastic assembly can be made in different color to differentiate the separate parts, and clear plastic can be used where transparency is desired to see interior construction and accessibility.

Producing the Plastic Models

Procedures for making plastic models depends on the type of prototype—whether it is a sheet-plastic assembly, or a solid cast plastic. To make a sheet-plastic assembly, the model maker works up forms in wood plaster or clay. For each "stamping" in the assembly he makes up a form. Patternmakers work in wood; clay modelers with a special clay and plaster. Scale may be $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ or full size.

The wood pattern has sheet plastic formed over it by pressure or vacuum techniques. So good is the detail and faithful adherence to form that the shaped plastic sheet is a perfect reproduction of the part as it would be in metal it is wrinkle-free and the trim line scribed on the pattern is reproduced on the plastic part to trim to. Only one shaping operation is required for plastic, whereas in making a steel counterpart of a deep-drawn stamping, many operations would be needed. Back drafts and difficult drawn areas can be readily performed. When all the components of the assembly have been formed and trimmed, they are fastened together with removable small brass paper fasteners.

If a clay form is required in order to fair-in contours, the model maker mounts male templets on a grid board, packs up clay, and uses female templets to fair-in the contours at important "stations." The areas between stations are scraped to contour.

The completed clay form is surrounded with a liquid tight inclosure and cold-forming rubber is slowly poured in at one end to avoid bubbles in the liquid. When the rubber has cured, it becomes a female mold, into which casting resin is poured. The cured resin now becomes the form block for the plastic prototype panel.

Solid plastic prototypes of castings, forgings, extrusions, die-castings, and other solid objects are made by casting rubber molds around a wood model. Coring is used for some holes and cavities, and screws are placed properly in the casting area if tapped holes are wanted, or integrally-cast studs desired. Casting resin is poured into the rubber molds and allowed to cure. Several duplicates are made for use by various specialists.

Ford has found that plastic prototypes generate ideas from both engineering and manufacturing staffs much sooner than by the old and universally used process of tooling up from detailed part and assembly drawings. At the outset, best practices in respect to casting, machining, forging, assembly, automation, materials handling, welding, and many other manufacturing aspects are incorporated in the design. Opportunities to apply new methods are foreseen, and there is time to work out the details of new and better processes. Thousands of hours of tool design are saved, because tool engineers can have parts to work with and see what they will have to allow for. Also, they need not fear major revisions in design.

The processing engineer can visualize all of the operations that should be needed, their proper order, the equipment that must be procured, and the manpower required.

Die engineers can see how to tip the part for best drawing results. They can suggest slight modifications in gussets, flanges, angle to ease the work or eliminate operations. Jointures that have started out with three or more complicated stampings in the ensemble have been reduced to one-piece stampings that are easier to make.

Welding engineers can check the design for accessibility to spot-welding tips, decide in advance which types of tips to use, foresee how guns would have to be applied and the production time cycle and manpower requirements. In general manufacturing engineers would have the means to balance out time cycles and make most effective use of labor.

It might be asked, "can't plastic prototypes actually revolutionize the activities of the product designer?" Key men, it would seem—those with the greatest creative powers—should now be able to express themselves faster and more thoroughly in plastic than they could on paper. They would make a layout as a point of departure, create prototypes without any detailing, feeling their way by alterations toward the optimum design. Spatial relationships, form, structure, and other design factors would quickly be determined. If stress coatings are applied, and the prototype properly tested, reliable stress patterns should be obtained. From such results, the product designer would refine his concept, then turn it over to a detailer for completion.

TECHNICAL NEWS

Navy Uses Mobile Working Models To Train Pilots and Mechanics

WHEN THE U. S. NAVY accelerated their air training program for pilots and mechanics, they discovered that they needed visual training tools to get across the operating characteristics of the AD series Aircraft. So the Special Devices Center of the Navy Research Bureau contacted the Douglas Aircraft Company, designers of the planes, and asked them to design and build a series of training panels for the Navy.

Wherever possible the panels were to incorporate the actual equipment installed on the airplane, and the operation of the systems was to be identical or closely simulated. In addition, the panels had to be compact and mobile so that they could be transported from one Naval Air Installation to another.

In a project that used engineers, writers, and illustrators, Douglas turned out 17 different units to describe the major systems of the plane. Procedure for designing the panels consisted of an illustrator drawing a perspective view of the system with the aid of parts lists and engineering drawings. And engineers then shuffled and arranged the actual parts until the unit was satisfactorily clear and technically correct.

Panels that explained systems with moving liquids required transparent windows in the lines to show speed and direction of fluid flow. Tanks were provided with lucite windows to show internal detail and simulated capacities.

The engineers removed parts of housings to show the operation of intricate mechanisms. When this made them inoperative, the exposed mechanism was mounted next to the operating part that was connected in the system.

Since simulation of temperatures and mechanical power factors generated by the engine in operation are necessary to give a true picture of the airplane's functioning, temperature bulbs were mounted on instrument panels. The instructor sets up desired temperature conditions by applying a match flame to the bulbs. Items like oil temperature and cylinder head temperature are indicated in this manner.

Where temperatures actuate motors or valves through thermostat or thermo-switch controls, the temperature bulbs of the control switches are surrounded by a simple heating coil. These are controlled by the instructor.

Safety devices were incorporated into each panel since it was expected that more than one student at a time would work the controls during study periods. Safety devices not only reduced chances of injury to students, but they also prevented damage to the training aids. For example, blinking red lights simulated the hot spark of the ignition system instead of an actual spark supplied by a hand generator.

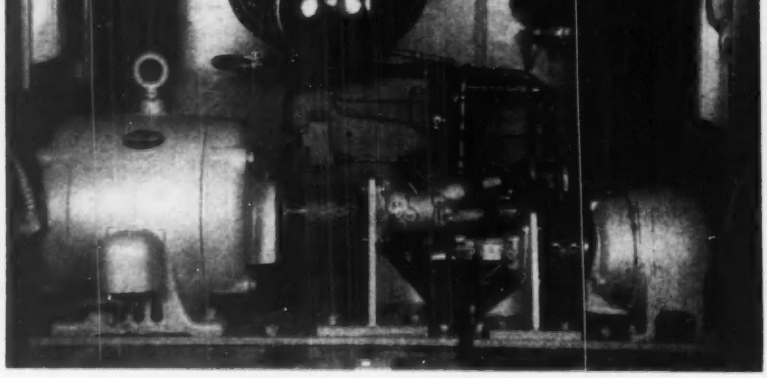
Since experience has shown that airplane hydraulic and electrical system failures are the most common, controllable failures were designed into these panels to teach trouble shooting and adjustment procedure. Diagnosis and correction of the malfunction on the panel is the same as on the airplane. A control box on the rear of the panel permits the instructor to set up troubles in the system without the student seeing him.

Pilots are put through flight problems on the panels at the same time mechanics may study maintenance problems on other units.

A typical problem on the panel units is for the pilot to close in on a target attack and return to an imaginary base. First, the student must select and arm his bombs and rockets. When the target is in range, he starts his assault by squeezing the button on the control panel.

As the bombs drop away, the instructor makes an adjustment and the engine splutters. The pilot must switch to another fuel tank and then start a return to his base. At the base, he starts landing procedure while the instructor sets up additional problems.

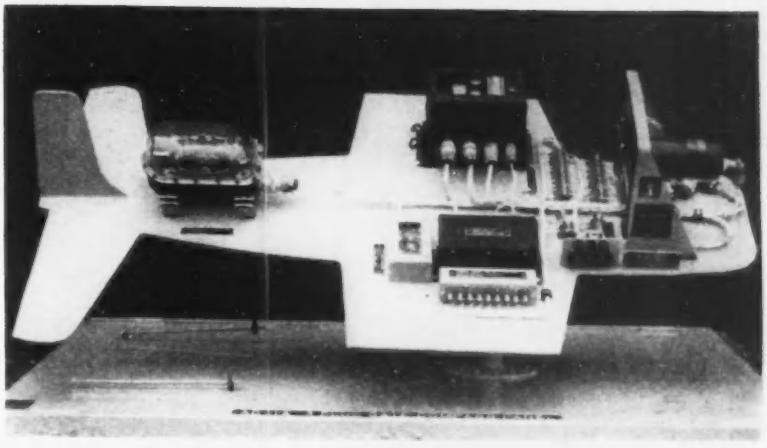
The 17 units are carried in 4 large moving vans that permit the Navy to carry the training aids to any Air Station in the United States. Instructors travel right with the properties so that all locations get the benefit of experienced teachers.



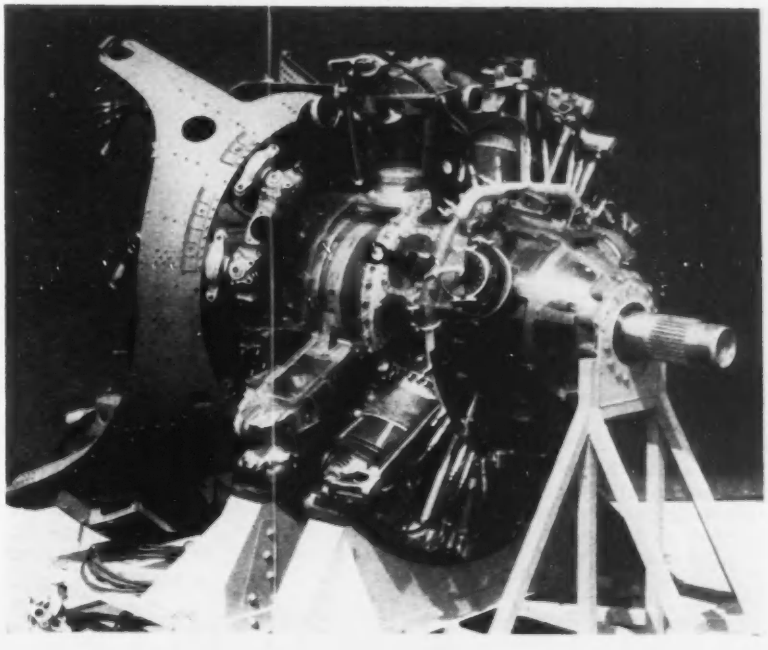
AUXILIARY POWER UNIT supplies hydraulic pressures to operate the landing gear panel and the Hydraulic System Panel. The former requires regulated pressures for correct operation, the latter has its own regulating equipment and requires unregulated pressures. Pumps are electrically driven, and the power unit contains the same components as in the airplane's hydraulic system. Normally it operates on 220 v, but it is equipped with an alternate 110 v system for use where the higher voltage is not available.

Another panel holds the complete "skyraider" hydraulic system which operates the same as that in the airplane. Adjustment and repair of the system on the panel qualifies a mechanic for work on actual airplanes. Instructors can set up a large number of hydraulic failures to test students and to teach trouble shooting techniques. These panels help develop an efficient combat team quickly and at a minimum expense.

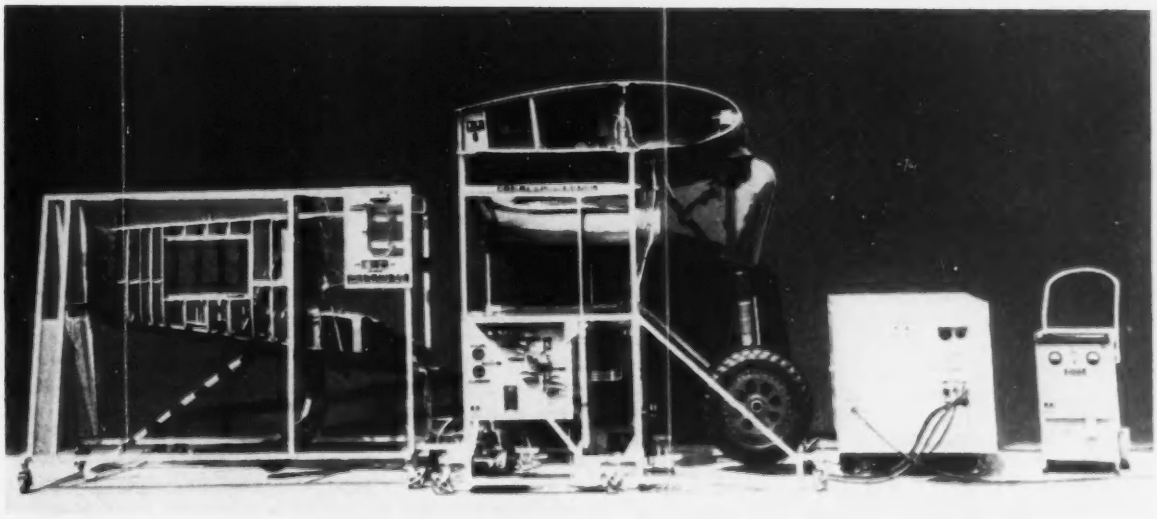
FLUX GATE COMPASS. Dummy airplane has an actual Gyro Flux Gate Compass system mounted on it so that instructor can explain intricacies of operation. The model airplane revolves and gives compass headings in the same manner as the airplane. Flux gate transmitter has a lucite cover so students can study its internal workings during operation.



ENGINE PANEL consists of a specially prepared double bank radial engine that has some metallic parts replaced by lucite to show details of construction and operation. Other portions of the engine are omitted entirely so that students can see inside the engine. This panel like all sixteen others is mounted on wheels for easy maneuverability in setting up the outdoor classroom to train pilots and mechanics.



TAIL GEAR AND ARRESTING HOOK SYSTEM (left) and Main Landing Gear system (center) are used to teach emergency landing gear procedures to pilots. The panels are powered by auxiliary hydraulic and electrical units at the right. Height restrictions on the Main Landing Gear prevented mounting the center wing section which houses the actuating equipment at a sufficient height to allow extension of the landing gear. The solution was a panel assembly stand that could be elevated to provide room for the landing gear to be raised and lowered. It necessitated an additional unit not found in the plane, an Auxiliary Hydraulic Power Unit to supply hydraulic pressure for operation.



O. A. (BUD) WHEELON, production design engineer at Douglas Aircraft Company, has been awarded the Wright Brothers Medal by the Society of Automotive Engineers for his published analysis of problems involved in the use of titanium for airplane design and construction. The SAE Award Committee voted Wheelon's paper the best presented in 1951 in the field of aerodynamics and airplane design. In addition to this work on titanium, the Douglas engineer has directed studies on the application of 75S aluminum alloy. Recently he developed a compact, efficient high-pressure hydraulic press (see page 139) which shows promise of widespread use in airframe manufacturing and other metal working industries. Wheelon is a graduate of the University of Iowa.

Radioactive Cobalt Helps Explain Why Porcelain Enamels Adhere

USING SENSITIVE RADIOISOTOPE TRACER TECHNIQUES, the National Bureau of Standards is studying the mechanism by which cobalt oxide promotes the adherence of normally processed porcelain enamels. By following radioactive cobalt that had been added to the frit, NBS researchers found that a metallic cobalt layer was formed at the enamel-metal interface, and that near the interface the enamel layer was depleted in cobalt oxide. Apparently it is this cobalt layer that is responsible for the property of good adherence in porcelain enamels with cobalt dioxide added.

The amount of cobalt that migrated to the interface increased with increased firing. Under normal firing conditions this layer was about 0.4 millionths of an inch thick and did not penetrate into the enameling-iron base.

In this study, small specimens of 18-gage enamel iron were coated with a porcelain enamel to which radioactive cobalt oxide had been added. And samples were underfired, normal fired, and overfired. The specimens were then de-enameled with molten sodium hydroxide. After the iron oxides were removed by agitation in sodium citrate solution, the radioactivity of the material was measured to indicate the amount of cobalt at the interface.

Cobalt distribution near the interface was pictured by making an autoradiograph of a large scale section ground at a slight angle. This showed that the radioactive material concentrated at the interface.

However substantial penetration was observed if the coated specimen was refired at 1,300 F for 270 hr after normal firing. Autoradiographs indicated considerable activity below the surface of the iron.

The cobalt deposit is believed to be metallic because it is removed with the iron base by treatment with a solution of iodine in potassium iodide. But the NBS experiments do not indicate whether the cobalt deposit consist of the pure metal or of an alloy with iron, nickel, or both. Continuing studies will attempt to clarify this phase of the problem.

Navy Recommends Design Changes for Tropical Communications Equipment

WASHINGTON—After a four year study in Panamanian jungles, the Navy has found that current specifications for tropical communications equipment were inadequate and recommended these improvements:

1) Eliminate fungus suspectible materials such as natural fiber cable lacings, cotton insulation, cellulosic plastics, and vinyls containing susceptible plasticizers.

2) Develop flexible glass-to-plastic bonding cements or nonwelling plastics for meter cases and tube sockets.

3) Protect ferrous parts more completely because they rust severely, particularly on areas where condensed moisture can accumulate. Conventional pigment finishes in addition to cadmium plating or other acceptable surface treatment are suggested.

Eighteen units representing four types of receivers were tested by personnel of the Naval Research Laboratory of ONR at the laboratory's Tropical Exposure Station in the Canal Zone. The equipment represented two levels of quality: very good and poor. Eight of the sets were uncoated, while the other 10 were treated with moisture- and fungus-proofing varnish to meet current naval specifications.

The higher quality receivers were found to be superior to the lower quality ones because of their resistance to physical deterioration. This was attributed to the avoidance of fungus-susceptible materials in the better sets, the exclusion of finishes that have poor corrosion resistance, and better cases.

Only two of the 18 receivers survived 44 months exposure without requiring component replacement, complete realignment, or both. The Navy reported that power units, resistors, potentiometers, and mica capacitors were the principal sources of trouble.

RESEARCH: New Data Developed on Stress Corrosion

INVESTIGATIONS AT the National Bureau of Standards, conducted by Hugh L. Logan of the NBS corrosion section, provide new data on some of the mechanical and electrochemical phenomena involved in stress corrosion cracking. Caused by the combined action of stress and corrosion, this effect can be responsible for the spontaneous service failure of objects ranging from brass cartridge cases to stainless-steel coffee urns.

Corrosion is generally considered to be an electrochemical phenomena, in which minute electrical currents flow between areas of different potential. When most metals are exposed to ordinary atmospheres, a thin oxide film is quickly formed that tends to protect the metal from further corrosion. According to the most general accepted theory, (which the NBS study tends to confirm) stress-corrosion cracking starts with a scratch or break in this protective film. When the protective film is broken through, the freshly exposed metal is more anodic (more negative) than the surrounding film-covered surface. If moisture is present an electric current flows that causes the metal to be removed from the exposed area.

To get a better understanding of the forces at work in stress corrosion, the NBS investigators measured electrochemical potentials of five alloys in normal film-covered and film-free conditions, both stressed and unstressed. Specimens were immersed in a suitable electrolyte, and potentials were determined using a calomel reference electrode of the saturated KC l type.

Studied were aluminum alloy, a magnesium alloy, two brasses, a low-carbon steel, and a stainless steel. The researchers first measured potentials for unstressed specimens having normal thin oxide films resulting from ordinary atmospheric exposure. They then measured potentials for the same specimens after the filmed surfaces had been removed by abrasion.

Each metal studied was more cathodic (more positive) in the normal film-coated form than in the abrazed form, by amounts ranging from about 0.12 v to 0.76 volt.

The electrochemical solution potentials of the same alloys, in the normal film-covered conditions, were then measured with stress applied. It was postulated that, when tension is initially applied to a metal, small breaks develop in the protective film, giving corrosion a chance to get started before a fresh film can form. If the electrochemical potential of the unprotected area alone could be measured, it would presumably be roughly the same as that of a film-free surface.

Measurement of change of potential with stress has been attempted before, but the attempts have generally been unsuccessful. In the past, it has been difficult to measure because the total area of conducting-through-film-covered surface of the specimen has been very much larger than the area in which the film is broken under stress.

NBS solved this measurement problem by coating an entire notched specimen with a non-conducting waterproof lacquer, then using a razor blade to remove a narrow band of lacquer at the root of the notch. With specimens thus prepared the only potential being measured was that of the narrow band of metal at the root of the notch where the stress was concentrated.

With fairly rapid application of stress, the film-free area became a substantial fraction of the total non-lacquer covered area, and the potential became more negative as the stress was increased. If the stress was held constant for some time, the solution potential generally reverted quickly to that of the unstressed metal. If the stress was increased rapidly, however, the measured potential tended to approximate that of the film-free surface as the point of fracture was reached.

Results are listed below.

Electrochemical Solution Potentials[1] and Maximum Change In Potentials With Stress

Alloy	Electrolyte	Electrochemical Solution Potentials Unstressed Specimens		Maximum change in potential with stress
		normal film volts	fill-free volts	volts
24S–T4 aluminum alloy	KCl (saturated)	−0.67	−1.43	0.610
70 percent Cu–30 percent Zn brass	5 percent NH_4OH + 5 percent $(NH_4)_2CO_3$	−0.47	−0.96	0.700
61 percent Cu–36 percent Zn–3 percent Pb brass	5 percent NH_4OH + 5 percent $(NH_4)_2CO_3$	−0.39	−0.98	0.510
AZ31 magnesium alloy	3.5 percent NaCl + 2 percent K_2CrO_4	−1.51	−1.645	0.240
Low carbon steel	5 percent NH_4NO_3	−0.60	−0.72	0.160
Type 302 stainless steel	KCl (saturated)	−0.28	−0.78	0.315

[1] With respect to calomel reference electrode of saturated KCl type.

New Developments In Corrosion Protection

DR. H. H. UHLIG, head of Massachusetts Institute of Technology's Corrosion Laboratory predicted that new developments will soon be available to help designers in the fight against corrosion. Speaking at the Northeast Corrosion Conference, Uhlig made these predictions:

(1) The use of cathodic protection will be extended to protect metals against stress corrosion and fatigue.

(2) Development of pore-free nickel coatings will permit the use of thinner coatings of this hard-to-get metal.

(3) Bright zinc or zinc alloy coatings protected by a clear lacquer will be a possible substitute for nickel coatings.

(4) Nickel molybdenum (Hastelloy) plating will coat steel in contact with hydrochloric and sulphuric acids.

(5) Titanium clad steel will protect hot water tanks against pitting and corrosion cracking caused by waters containing chlorides. Metals exposed to mine and other acid waters will also be protected by titanium cladding.

(6) Aluminum coatings will provide resistance against nitric acid and sulphur-bearing atmospheres.

(7) Wash primers like polyvinyl butyl will be widely used because they combine surface treatment and priming into one operation.

(8) Tetrafluorethylene, a material that is corrosion resistant at high temperatures, will be added to paint formulas to increase protection.

MATERIALS: Bolivian Revolt Won't Affect U.S. Tin Supplies

THE BOLIVIAN REVOLUTION and the new regime's talk of nationalizing the tin mines won't bring any new restrictions on U. S. tin users. The Reconstruction Finance Corporation has already guaranteed enough tin to meet most current U. S. needs.

Exclusive of stockpile needs, the U. S. minimum tin requirements for this year are 62,000 tons. Contracts already signed will bring in 53,000 tons, and the RFC has bought an additional 9,000 tons on the open market, primarily in Thailand and Portugal.

However, resumption of shipments from Bolivia are important since the stockpiling of tin was suspended in November 1951 and cannot be continued until imports increase substantially.

NPA allocates about 5,000 tons each month. While this has been adequate to meet most military and civilian needs, private inventories are low and manufacturers are anxious to build up their stocks.

U. S. pig tin consumption in 1951 dropped 13 percent from 76,308 long tons to 60,812 as a result of NPA allocations. Major declines in tin use include tin plate, solder, and tinning; these were 13,000 tons under 1950 consumption. Only 57,000 tons of tin concentrate and metal were imported in 1951, compared with 108,797 of the previous year.

As a result of the drop in imports, government and private stockpiles dropped from 40,986 tons in January 1951 to 19,646 in December 1951.

When RFC and Bolivia iron out their differences, NPA will probably relax use restrictions. But allocation controls will not be dropped until private inventories and the national stockpile are rebuilt.

Zinc Surplus Expected This Year

SUPPLIES OF ZINC are so plentiful that all restrictions may be removed at any time. Stockpiles have been built up and an excess of 70,000 to 100,000 tons over consumption is expected this year.

The American Zinc Institute at their 34th annual meeting heard that the adequate supply situation would continue barring strikes and a collapse of the market price of zinc.

Eastern producers reported that their production will be 15 percent higher in 1952 than last year. And only one mine in the area is nearing exhaustion. The production loss from this operation will be offset by a new mine scheduled to start production about the same time the exhausted mine is closed. In addition, new discoveries in eastern Tennessee will further increase output when they go into production.

Montana mine operators indicated that their production was up as a result of new zinc discoveries in abandoned copper mines. In the next five years they expect to double present production of about 50,000 tons.

In the Southwest, mine production will break a new record in 1952 when 190,000 tons of recoverable zinc are produced. While some mines in Arizona are nearing depletion, zinc reserves in the entire area will permit this high level of production to continue for several years.

Zinc ore production in California and Nevada could stretch zinc supplies in an emergency, but it is heavily dependent on price conditions. Now producing about 26,000 tons a year, the area could jump production to between 50,000 and 100,000 tons if transportation charges were pared.

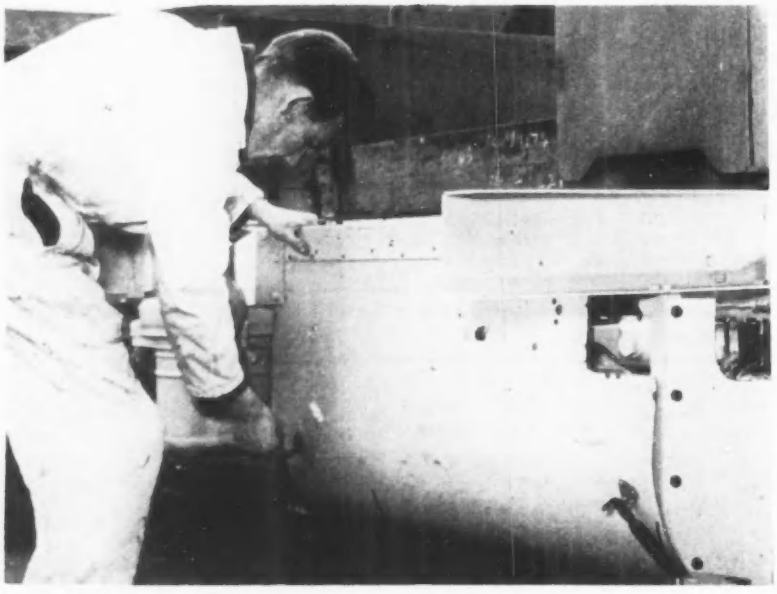
In Nevada particularly, freight charges often exceed the total cost of mining and milling the complex ores found in the area. However, the construction of ore processing plants between the mines and factories will materially reduce transportation charges.

Several companies owning mines in this area (Combined Metals Reduction Company, Comet Mines Inc., and Eureka Corporation) have extensive development programs underway to evolve more economical methods of treating low grade zinc ores. Current progress indicates that new methods will permit a considerable production expansion in this area during the next twenty years.

U. S. zinc production added to imports of 113,000 tons, should provide at least 1,018,000 tons for American industry this year, compared to 967,000 used in the peak year of 1950.

Lead Is In Easy Supply

NATIONAL PRODUCTION AUTHORITY is considering the removal of all restrictions and controls on lead as a result of the abundant supply. Lead is so plentiful that users aren't building up the inventories permitted by NPA. Most significant feature in the lead picture was the big per-pound drop in price effective in May. This was the first U. S. price decrease in the nonferrous metal market since the outbreak of Korean hostilities.

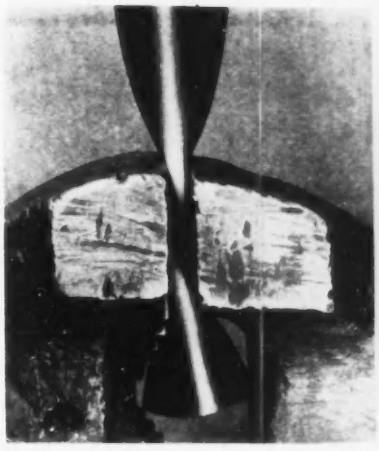


QUIETER BUS RIDES FOR BRITONS are the result of the sound insulator pictured here which isolates engine noise in Leland Motors, Ltd. Royal Tiger Buses. Made from aluminum sheet lined with thick linoleum, the acoustic shroud prevents engine noise from leaving the compartment to strike the road surface and echo up along the side of the bus. The insulator, supported by steel angle brackets and held in position by spring clips, is detachable for engine maintenance and easy access to engine compartment.

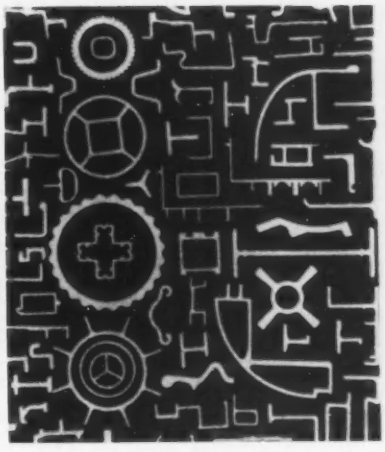
But Pinch Remains On Some Metals

WHILE MOST METALS were getting more available, others remained on NPA's critical list with no prospects for improvement this year. Leading the list are nickel and cobalt. Despite continued conservation measures, nickel output is far behind nickel demand and there is no relief in sight for civilian goods in 1952. Temporary balance exists between supply and demand for cobalt, but increasing military demands prevent any boosting of allocations.

Columbian, molybdenum, tantalum, and tungsten remain critically short. Now in approximate balance are chromium, manganese, silicon, vanadium, boron and ferrotitanium.



SQUEEZED NEARLY FLAT IN A VISE, this pipe made from Bakelite Company's new high-impact resistant plastic does not crack or craze. Available in three grades, the rubber-modified styrenes are easy to mold, extrude and machine. Bakelite also claims they combine excellent electrical properties with light weight, and maintain high impact strength to —5F.



ALUMINUM EXTRUSIONS are developing as important structural design materials. Pictured here are cross sections of typical shapes supplied by the Reynolds Metal Co. Reynolds predicts an increasing demand for these sections particularly in construction and other industries where weight and corrosion resistance are important factors affecting design.

Du Pont Tests New Synethic Rubber

DU PONT CHEMISTS revealed to the Rubber Division of the American Chemical Society that they had developed a new synthetic elastomer, which they claim has improved properties over other synthetic rubbers. Called "Hypalon", S-2, the material is being evaluated for applications in the automotive, wire and cable, protective coating, and mechanical equipment industries.

The elastomer is made by treating polyethene resin with chlorine and sulfur dioxide to produce a rubber-like material that can be compounded and processed in conventional rubber machinery. It can be blended with natural and synthetic rubbers and imparts to the blend many of its properties.

One of the outstanding properties of this white spongy material is its high resistance to ozone, which contributes to unusual weather durability. It also has improved resistance to heat and abrasion, and does not require the addition of carbon black for reinforcement. This permits fabrication of the material without limit as to color and may extend its use.

Ozone protective films can be applied to thick rubber sections from solution or as a calendered sheet. Du Pont reported that ozone failures had been completely eliminated in gaskets protected by Hypalon S-2.

Electrical properties are comparable to those of other chlorinated elastomers. That means the material will probably by adequate for low voltage insulation but unsatisfactory for high voltage primary insulation. Volume resistivity appears to be better than some elastomers currently used for wire jacketing.

Though still in the early stages of development, Du Pont predicts Hypalon S-2 will have extensive use for tire treads, coated fabrics, protective coatings for rubber and gasket materials, and wire and cable coverings.

Reinforced Plastics Is New Material For Military Items

THE MILITARY SERVICES have gotten interested in reinforced plastics as a result of Navy success with it for shipboard piping. All three services are now building reinforced plastic experimental and pilot models of equipment: The Army, water tanks; the Air Force, radomes and airplane ducts; and the Navy, whaleboats.

While all three are conducting research on the material, the Naval Ordnance Laboratory has the best equipped setup. NOL technicians see reinforced plastics as a construction material, not merely a substitute. They plan to use it in certain applications no matter how steel, copper, or other metal is available.

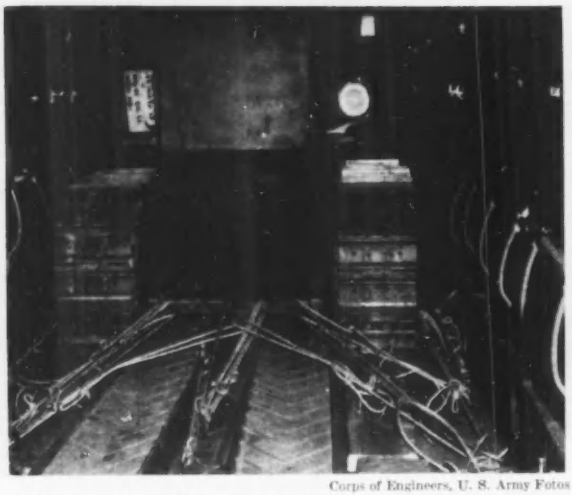
They have already built a number of secret experimental items where the material has replaced brass and steel. Engineers are currently studying the design and construction of these structures, measuring the properties under service conditions, and developing improved resins, reinforcements, and fabrication techniques.

Reinforcing materials being studied include: paper, cotton duck, nylon cloth, unwoven glass yarns, and woven glass cloth. So far, highest strength per unit weight has been obtained with glass fiber reinforcements because of the exceptional strength of fine spun glass fibers. Glass cloth reinforcing is being used to make ordnance components, and glass filaments and yarn reinforcing show promise for nonmagnetic tubing and shipboard piping.

Teflon Discoverer Wins Award

DR. ROY J. PLUNKETT, of the Dupont Company, has won the 136 year old John Scott Award in recognition of his discovery of Teflon, tetrafluorethylene. The Award which consists of $1,000 and a copper medal was announced by the Board of Directors of City Trusts of Philadelphia, who administer it.

Dr. Plunkett was engaged in research on fluorocarbon refrigerants when he developed this polymerized fluorocarbon. The chemical industry accepted it quickly because of its exceptional corrosion resistance. Other industries found that its electrical and mechanical properties made it suitable for widespread use. The material is also anti-adhesive and there is no known cement that will bond it.



Corps of Engineers, U. S. Army Fotos

AIR TRANSPORTATION REQUIRES that commercial tractors be modified so that they meet the weight limitations of the airplane and can be easily tied down. This airborne model has lashing rings that provide a large number of tiedowns.

BULL DOZER ADAPTED FOR ARCTIC USE has cab with special heater and spring loaded quick-opening doors to permit the operator a fast escape if the unit crashes through ice. A starting engine replaces the standard batteries.

Korean Action Tests Army Engineer Equipment Designs

FORT BELVOIR, VA.—Engineers at the Engineer Research and Development Laboratories, are modifying and developing equipment to fit changing combat conditions reported from the battlefronts of Korea.

In bridge design, increased live loads demand wider and stronger bridges. And low alloy steel is still the most important, dependable and available material for fixed and floating bridges. Panel type bridges have proved themselves to be the most economical and satisfactory for general purpose tactical use.

Floating bridges still use pneumatic floats because of their adaptability to a variety of bank conditions, their lightweight, and their ease of handling and packaging for transport.

Wood, aluminum and plastics are under study as substitutes for steel, but none have been classified as acceptable as yet. The Corps of Engineers is working with the Society of the Plastics Industry to find the best ways of using plastic as a structural material. Fiber glass reinforcing has given rise to a promising new material that is resistant to attack from chemicals and organisms; and is lightweight and strong.

In the design of aircraft and road construction equipment, the engineers still depend on standard industrial equipment with slight modifications. The use of commercial equipment gets rid of costly and time-consuming development of military specials as well as simplifying the problem of large quantity procurement.

However, there are four types of modifications required: (1) adaption for military transport; (2) adaption for special tactical requirements; (3) weather proofing for tropical and arctic operations; (4) adoption for easier operation and maintenance.

Engineer equipment must be designed so that it is transportable by air, sea and land. Therefore, it cannot exceed the limitations of weight and dimensions imposed by cargo aircraft and landing vessels. In addition, the items must be equipped so that they can be easily loaded, lashed down, and unloaded.

Easy maintenance requires interchangeability of parts and assemblies among various types of equipment. As a result, the engineers are developing a family of standardized industrial engines from 15 to 225 hp that will reduce the number of spare parts required. They are also developing a general purpose family of generators from 500 w to 5 kw smaller and lighter than current designs. Using air-cooled engines, the generators will produce 60 cycle and higher alternating current for U. S. and British equipment.

AUSTERITY PROGRAMS: Cut Costs and Save Materials Here and Abroad

WITH MATERIAL SHORTAGES and high prices affecting product designs on a world-wide basis, organizations on both sides of the Atlantic are adopting austerity programs of one degree or another to keep production figures high. Two such programs, developed for different reasons and with different formats, are in effect at the Ordnance Department's Detroit Tank Arsenal and the British Hoover Company. The Arsenal had to cut costs; the vacuum cleaner manufacturer had to save critical materials to stay in business.

In Detroit, the approach was to strip down a medium tank and display every part and component so that arsenal employees and commercial suppliers could inspect the display and make suggestions to reduce costs by (1) substituting less expensive and less critical materials; (2) simplifying designs to save materials and production costs; (3) getting rid of unnecessary components and luxury gadgets.

Over 1,000 employees viewed the display and turned in 750 suggestions. Shop people offered almost 500 different improvements, of which 240 were considered to have possible use. In the first six months of the campaign, the suggestions turned up possible savings of $12,000 per tank.

The arsenal's research and development department has the responsibility of screening all suggestions and turning those with potential use over

to the engineering section concerned for test and study. If the idea turns out to be a money saver and does not reduce the tank's performance, it is recommended for adoption. Such suggestions are passed on to commercial tank builders who must also use the new design on the tanks they are building.

Changes affecting only method of production or materials can usually be instituted by the arsenal. But if the design change affects the military characteristics of the tank, Ordnance Field Forces must approve the suggestion before it can be incorporated. This prevents over enthusiastic economy at the expense of combat performance. For example, an arsenal engineer came up with the idea of getting rid of the auxiliary generating equipment, that every tank carries. The tank's primary power plant is more than sufficient to supply electrical needs, and outlets are provided to run electric lines from one tank to another if this plant should fail. However, field experience had shown that this auxiliary equipment was essential in a certain combat emergency situation, so the field forces vetoed the idea even though it would have meant a considerable cost saving.

Arsenal officials incorporate the changes into production slowly so that productive levels are not altered. Components and parts that are to be replaced are used until stocks are exhausted. Or if they are on order, until the order is exhausted so that the government does not have to pay cancellation penalties.

Some of the design changes save only a few dollars per units, but others make significant economies. An engineer looked at the transmission and came away with a new design for this unit that may save $4,600 per unit. Prototypes of this design have been built and are being tested. Preliminary studies indicated that the new transmission, which has half the number of parts of the one now used, will perform better, will be more reliable and easier to maintain and will be lighter in weight. Initial costs are cut from $10,670 to $6,070.

Changing from magneto ignition to a conventional automobile distributor system will save money two ways. Initial costs will be cut from $686 to $281; and the new system will use standard spark plugs instead of special platinum plugs that cost two dollars apiece more.

Taxpayers are in for a $400 saving per tank if a new steering control unit goes into production. Replacing the wobble stick unit that costs $450, a new steering wheel-control under test is priced at only 50 dollars. A shop suggestion to change the driver's seat will save $185.

British Austerity

At the British Hoover Company, the problem was: use critical materials at maximum efficiency or be shut down most of the time. The company assigned top level management executives with full time materials conservation responsibilities to the job.

The company set up a material conservation committee under the direct supervision of the deputy managing director. This committee appointed five subcommittees: three technical committees, one for each geographic group of factories; a publicity committee, and a sales policy committee.

The technical committees originate plans and receive suggestions for material saving. They study these proposals and evaluate their worth. They are also charged with following up their recommendations to see that design changes are made and results are obtained. While costs are one factor in this evaluation, sometimes uneconomic decisions are made because of the extreme scarcity of certain materials.

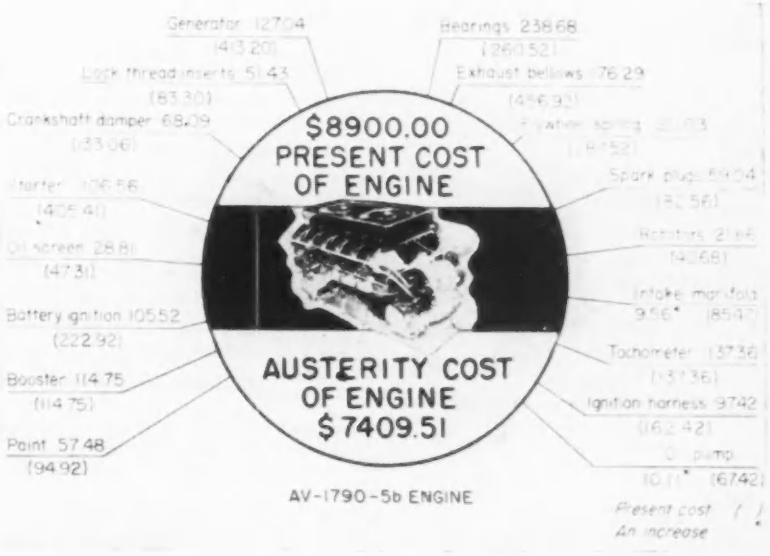
Certain limitations have been set on suggestions by the Sales Policy committee. Mainly, no proposed change can drastically alter the appearance or reduce the quality of the product. But even with this limitation, the company recently redesigned their vacuum cleaner to save materials.

In the new design, Hoover puts into the final product 95 percent of the sheet and strip steel they receive; 85 percent of the copper; and 62.2 percent of the brass. While they allow $1\frac{3}{4}$ percent of materials total cost for scrap, their figures actually average about $1\frac{1}{2}$ percent.

These low percentages of scrap are the result of an active waste ulitization program put into effect by the technical committees. For example, one factory was able to stamp four small parts from a piece of sheet steel left over from the manufacture of another part at a different factory. It saves $1\frac{1}{2}$ tons of steel a week. A waste lug from a steel stamping was used at another plant to replace a part formerly made from new steel; this saving amounts to 12 tons a year. Still another factory is saving 167 tons of steel a year by using leftovers to make small parts.

Some substitutions have not only saved materials but have also saved money. By finishing an agitator body in enamel instead of nickel the company saves 130 lb of material and $150 a week. Aluminum horsecollars instead of brass save 30 tons of the alloy and $15,000 a year. Improved armature windings have cut copper consumption by 11 tons a year. And the company even reduced the size of the label on its carton to conserve 1,400 lb of paper.

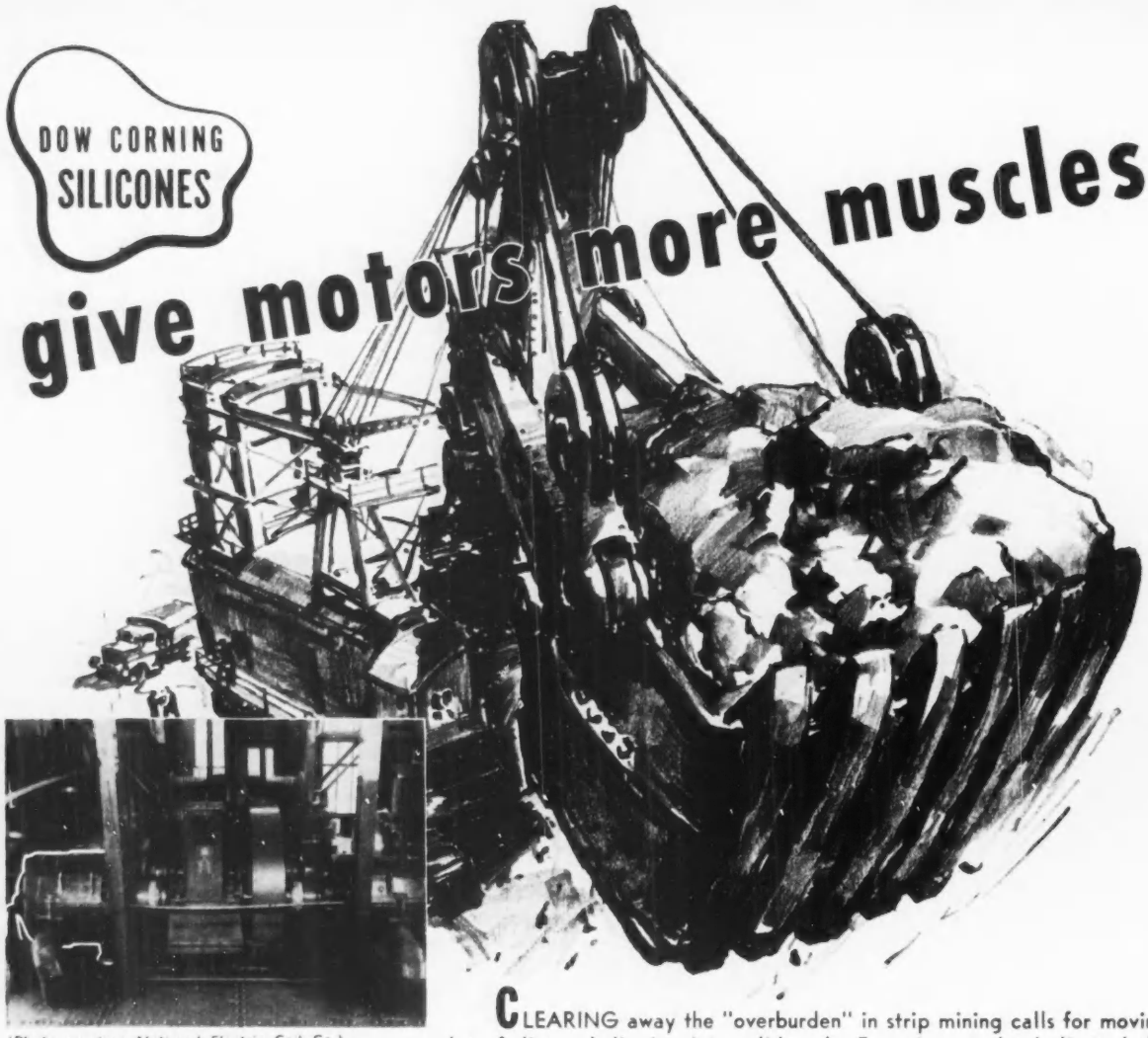
The publicity committee keeps suggestions coming in from the field. The entire program has enabled the company to stay in production even though the most enthusiastic estimates predicted they would have to shut down a good part of each year.



MINOR CHANGES IN A TANK POWER PLANT add up to considerable savings. These modifications, being incorporated in test engines, save taxpayers $1,490.49.

DOW CORNING SILICONES

give motors more muscles



(Photo courtesy National Electric Coil Co.)

On the hoist motor outlined above Class B Insulation failed 18 times in less than 8 years. Rewound with Class H Insulation made with Dow Corning silicones, the motor is still in excellent operating condition after 4 years of uninterrupted service.

LOOK AT THE RECORD

DATE AND CAUSE OF FAILURE

2/21/40 Armature coils grounded	7/28/45 Armature coils grounded
12/29/40 Armature coils grounded	9/14/46 Armature coils grounded
9/2/41 Open armature circuit	2/6/47 Armature coils grounded
4/13/42 Armature coils grounded	6/23/47 Armature coils grounded
4/18/42 Leads loose in commutator	9/17/47 Armature coils grounded
10/24/42 Armature band thrown	11/4/47 Armature band thrown
4/5/43 Armature coils grounded	12/26/47 Armature coils grounded
8/9/43 Open armature circuit	1/7/48 Rewound with Class H
10/7/43 Armature coils grounded	1949 No failure
9/30/44 Armature coils grounded	1950 No failure
10/18/44 Armature coils grounded	1951 No failure

CLEARING away the "overburden" in strip mining calls for moving a lot of dirt and digging into solid rock. Excessive overloads limited the service life of this main hoist motor to 5 months. Rewound with Dow Corning Silicone (Class H) insulation, the motor has already outlived its previous service record almost 10 times; has prevented at least 9 costly breakdowns at an estimated down-time rate of $1000 per hour.

That kind of performance has been repeated in thousands of different installations. That's why more and more production men in varied industries are insisting upon Class H insulation for their hard working motors. These may be critically important motors; motors subject to frequent overloads; motors operating in high ambient temperatures or exposed to a combination of heat and damp or corrosive atmospheres.

Users of Dow Corning Silicone (Class H) insulation are finding that it pays for itself over and over again. In fact, life expectancy of Class H insulation made with Dow Corning silicones is in the range of 4 to 100 times the life of Class B insulated equipment under comparable operating conditions. And Class H costs little more than the second best class of insulation.

For complete information on Class H Insulation, list of rewind shops or sources of supply, call our nearest branch office or write Dept. R-18.

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Stress Charts for Pressurized Elliptical and Oblong Tubes

J. C. WEYDERT
Purdue University

BASED ON PHOTOELASTIC MODELS, the nomogram and graph should prove useful to the designer confronted with sections that are either elliptical or oblong in shape and subjected to internal pressure. In the case of elliptical shapes, the maximum stress occurs at the inner surface on the major axis. The stress distribution is illustrated in Fig. 2. The nomograph in Fig. 3 is used to calculate the magnitude of the maximum stress.

With parts having an oblong cross-section, the point of maximum stress may be at the inner surface of the longitudinal axis or at the outer surface of the minor axis. The particular point depends on the section dimensions. The chart in Fig. 4 determines both the location and the magnitude of the maximum stress in these sections. This chart is divided into two regions to distinguish between the two different points of maximum stress.

Both graphs are based on the following paramaters:

$\frac{s}{p}$, stress-pressure ratio (1)

$\frac{a}{b}$, ovalness ratio (2)

$\frac{ab}{t}$, mean radius-thickness ratio (3)

where:

s = maximum stress, psi
p = internal pressure, psi
a = semi major axis, in.
b = semi minor axis, in.
t = wall thickness, in.

Example: Find the maximum stress in an elliptical tube having the proportions shown in Fig. 2 (A) and under an internal pressure of 1000 psi.

Referring to Fig. 3; with an ovalness ratio of 1.43 and a mean radius-thickness ratio of 1.89, Line 1 indicates that the stress pressure ratio s/p is 9.6. Thus, the maximum tangential stress at A is:

$s = 9.6 \times 1000 \times 9{,}600$ psi.

Example: An oblong tube has an ovalness equals ratio a/b of 1.54, the mean radius to thickness ratio is 4.25 and the internal pressure is 300 psi.

Line 2 intersects the 4.25 line in the B Region; thus the maximum stress occurs at point B. Line 3 indicates a stress-pressure ratio of 33. The stress is found:

$s = 33 \times 300 \times 9{,}900$ psi.

With a thinner wall tube, i.e. a mean radius to thickness ratio of 6.5; line 2 intersects the 6.5 line in the region where the critical stress occurs at point C. The stress-pressure ratio is found to be 70.2 (Line 4) and the maximum stress becomes:

$s = 70.2 \times 300 = 21{,}060$ psi.

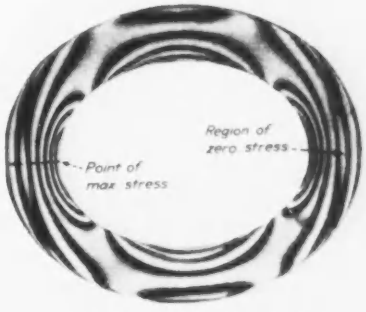
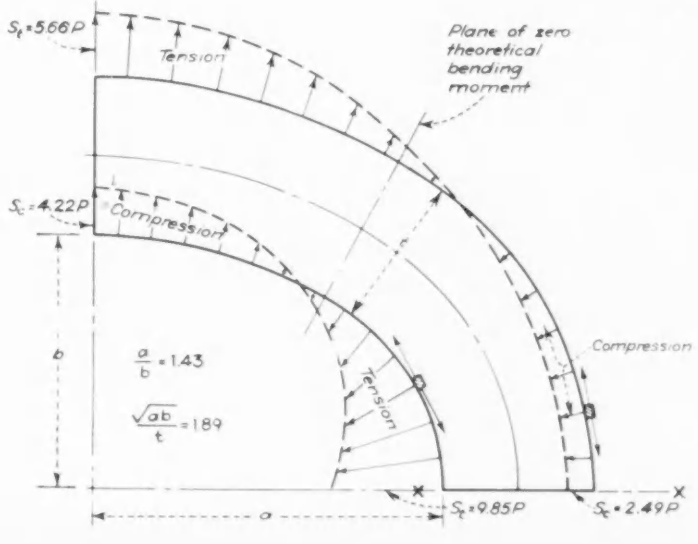


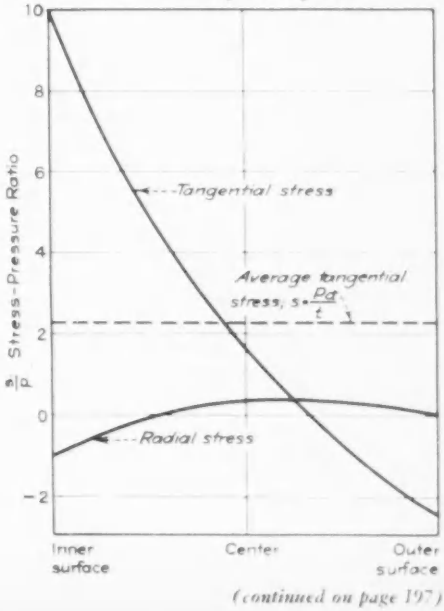
Fig. 1—Photoelastic fringe pattern of an elliptical pressure tube.

FIG 2

(A) Tangential Stress Distribution in an Elliptical Section



(B) Stress Distribution of Section X-X Along the Major Axis



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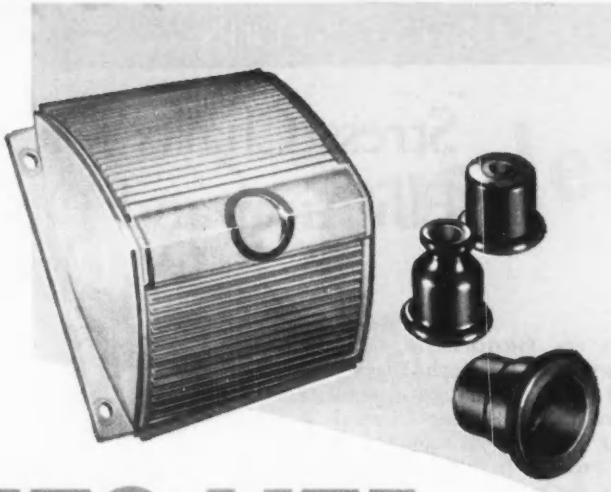
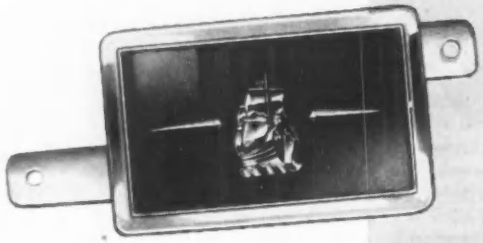
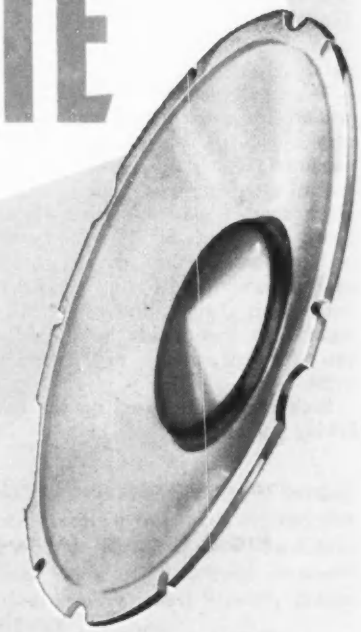
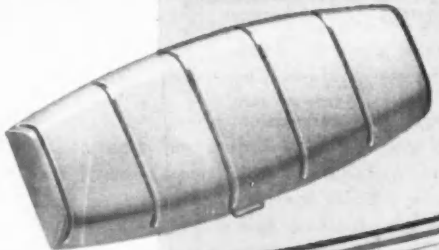
You're always right with AUTO-LITE

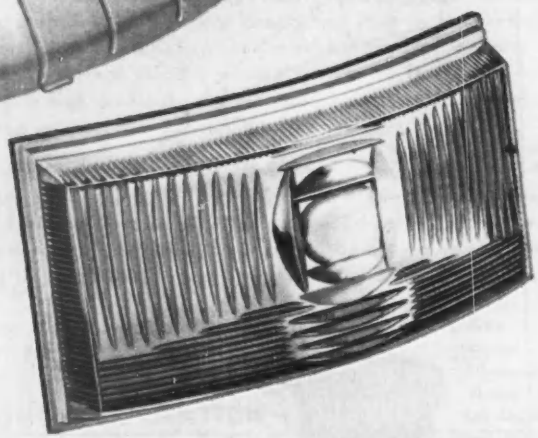
Plastics











• Plastics and plastic-metal combinations are opening new fields in design as illustrated by these few of many assemblies made by Auto-Lite. Here under one roof at Auto-Lite's great Bay Manufacturing Division in Bay City are the technical skills and production capacity for a new art rendered in plastics. The artistic skill of Auto-Lite's Art and Style Division is available on matters of design and development. Address inquiries to:

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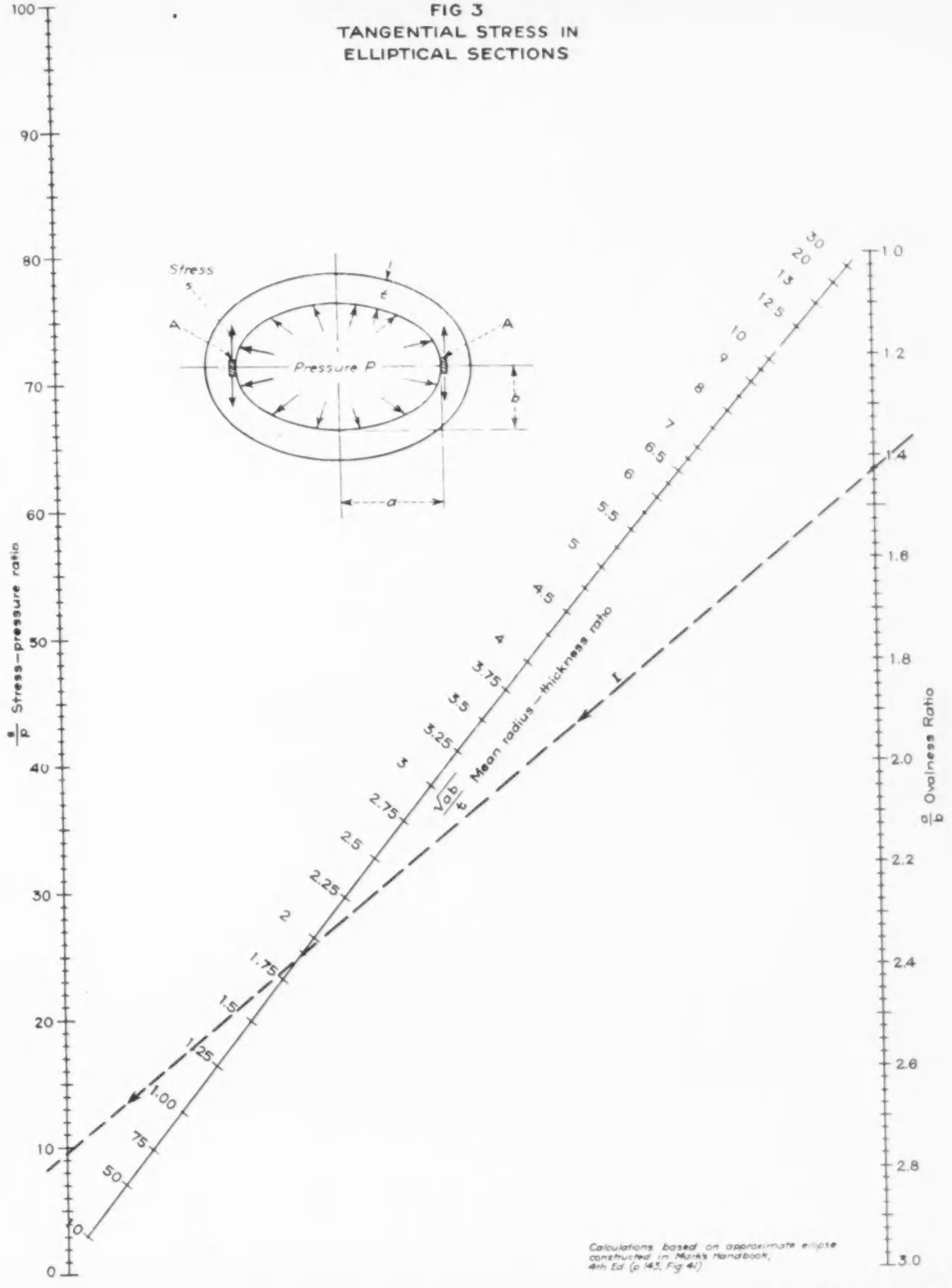
Stress Charts for Pressurized Elliptical and Oblong Tubes (continued)

FIG 3
TANGENTIAL STRESS IN
ELLIPTICAL SECTIONS



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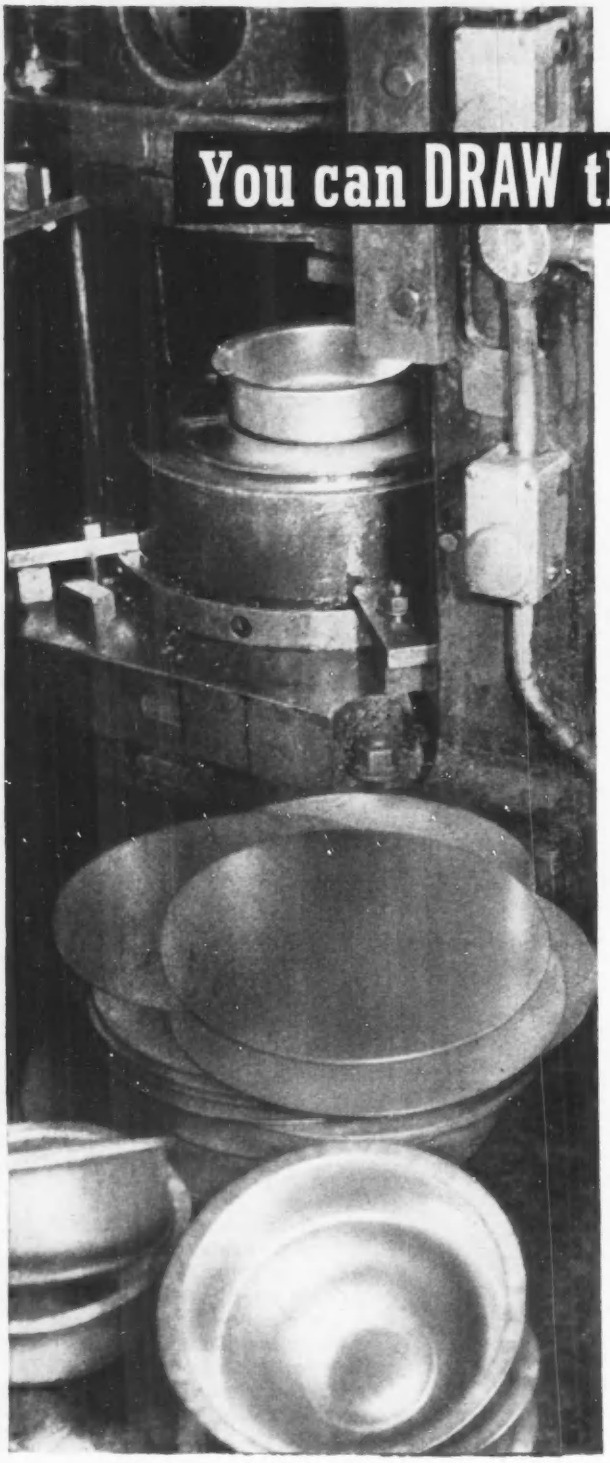


You can DRAW this Zinc-Coated Steel

No flakes, no breaks are found when these oil-reservoir bodies for heaters are drawn from blanks of Armco Drawing Quality ZINCGRIP Steel.

The specially-applied coating on Armco ZINCGRIP does everything asked of it. In one draw, the coating stretches perfectly *with* the steel base.

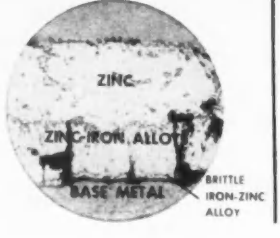
This means real production savings. And it means *complete rust protection* for fabricated products and equipment—on sharp bends as well as flat parts.

16-year service record

ZINCGRIP now has a record of more than 16 years in proved service. Created by Armco in 1936, it was the first sheet steel hot-dip coated on a continuous production line.

Armco ZINCGRIP is produced in sheets or coils. ZINCGRIP PAINTGRIP is a companion zinc-coated sheet steel for products to be painted. The ZINCGRIP steel is Bonderized to take and hold paint without pre-treatments of any kind.

The ZINCGRIP coating, after 20 per cent stretching, adheres tightly and protectively to the base metal. There is no brittle iron-zinc alloy layer.



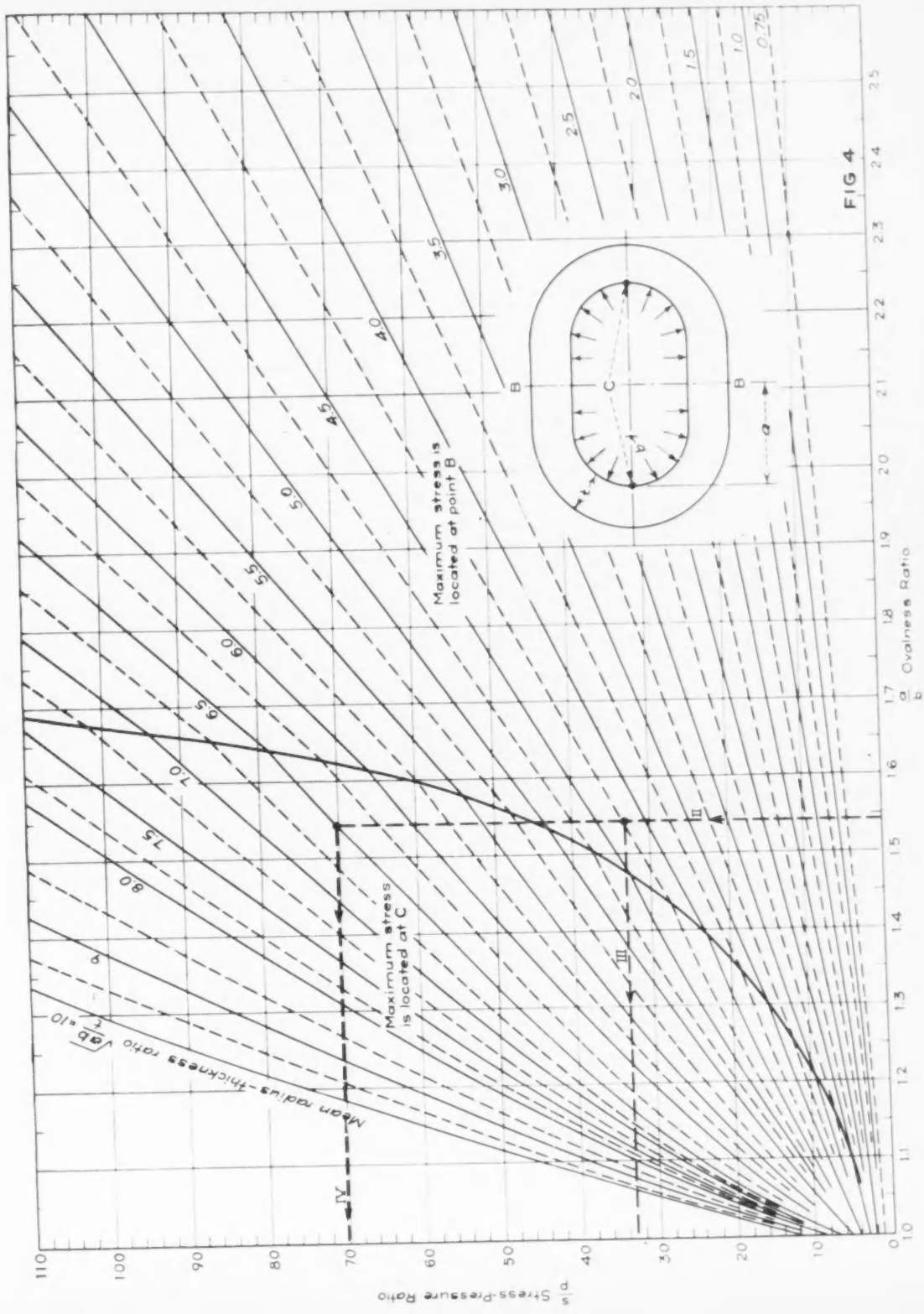
Cross-section of a conventional galvanized coating after the metal was stretched only 15 per cent. Dark areas are cracks which spread from the brittle iron-zinc alloy layer, causing the coating to flake or peel off.

ARMCO STEEL CORPORATION

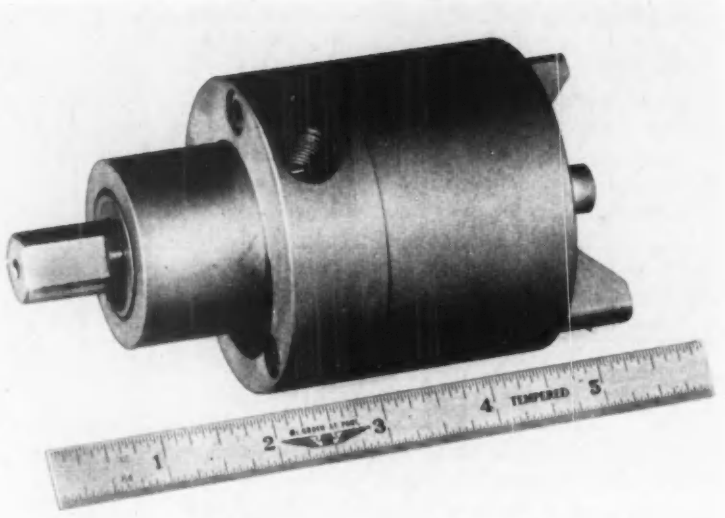
3062 CURTIS STREET, MIDDLETOWN, OHIO • PLANTS AND SALES OFFICES FROM COAST TO COAST • EXPORT: THE ARMCO INTERNATIONAL CORPORATION

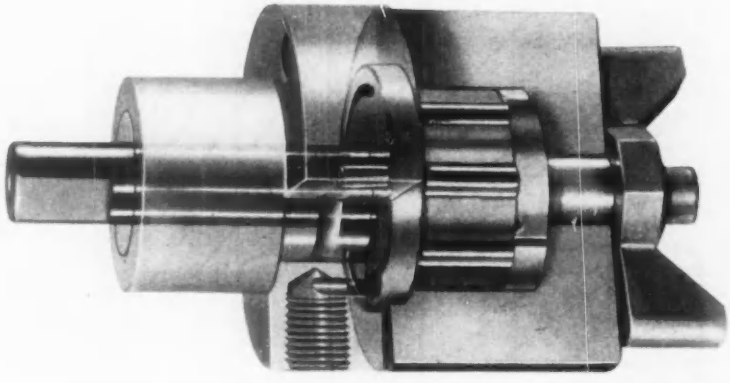
ARMCO

Stress Charts for Pressurized Elliptical and Oblong Tubes (continued)



Compact, Light Fluids Pump Uses Rolling Vanes





The new Magna Mite, offering a radical change in the design of vane type pumps, is a positive displacement pump of compact size, with capacities from $1\frac{1}{2}$ gpm down to $\frac{1}{4}$ gpm or less. This pump is suitable for handling fuel oil, gasoline, hydraulic fluid, lubricating oils, and other light viscosity fluids.

This pump is generally similar to vane-type pumps in operation and construction, but the difference is that the conventional vanes are replaced by rollers. The rollers contact the outer case as in a roller bearing, and rolling friction replaces sliding friction between the vanes and the pressure chamber. As a result, the life of the pump is said to be increased three to five times over that of the ordinary type vane pumps.

The action of the rollers against the inner periphery of the pressure chamber induces the formation of an oil wedge between the contacting surfaces to insure proper lubrication at this point. The vanes are hydraulically balanced.

The pump is cylindrical in shape, has a diameter of $2\frac{3}{4}$ in., and is 6 in. long overall. The size and shape are practical for applications where space is at a premium.

The Magna Mite is available in a choice of three major types: constant displacement (type A); adjustable displacement (type B); and variable and reversible displacement (type C). All three types will operate in either direction of pump rotation, and in any position. The illustrations show a type B pump. The type A pump is identical, except that the shaft runs only from the front of the pump to the rotor, and does not extend through the back cover to an adjustment screw. The type C is similar to the type B except that a steel ring is superimposed between the rotor and the housing.

The constant displacement and adjustable displacement models (types A and B) are suitable for machine lubricating applications or pumping fuel oil for industrial or domestic oil burners. In the type B pump, the discharge volume is easily adjusted by turning a thumb lever mounted at the back end. This adjustment can be made with the pump rotating or stationary.

Variable and reversible displacement is provided in the type C, and a lever may be used to permit either manual operation or remote automatic control. In this type of pump, with the motor and pump operating continuously in one direction, it is possible to: (1) Adjust the delivered fluid volume to suit the job. (2) Vary the volume delivered at any part of a cycle. (3) Reverse the flow. (4) Stop the flow.

The pump is furnished as standard with diametrically opposed ports having a $\frac{1}{4}$ in. pipe thread. Pumps are machined all over to close tolerances of +0.000-0.001 inch.

These pumps have a practical speed range of from 300 to 3,600 rpm, and are rated at 1,750 rpm. The rotor shaft has a flat for the driving connection. Antifriction or sleeve bearings are used, depending on the nature of the application and the smoothness of the fluid being handled.

Milwaukee Hydropower Inc.,
3447 N. 35 St., Milwaukee 16, Wis.

Electrically Controlled Air Control Valve

An electrically controlled four-way directional air valve, meeting group D, class 1, standards for wiring in hazardous locations, the EXV electroaire valve is a complete, packaged, explosion-proof, low voltage, air powered air valve. Built into one integral unit is a four-way directional slide valve, solenoid control units, and piston rod speed regulators. The valve may be used safely in atmospheres containing gasoline, petroleum, naptha, alcohols, acetone, lacquer solvent vapors, natural gas, or other volatile gases.

Electrically controlled, but air-powered, the electroaire valve differs somewhat from conventional solenoid operated air valves. Instead of using heavy power solenoids to shift the valve, the electroaire valve uses the air it directs to shift the slide valve. Small, sealed, 8 volt solenoids act as triggers to release the pressure of the incoming high pressure air against either side of a floating piston which operates the slide valve. The plungers of these small solenoid control units move only $\frac{1}{32}$ inch.

The solenoids will operate continuously at speeds up to as high as 2,200 movements a minute without hum, pounding, or overheating.

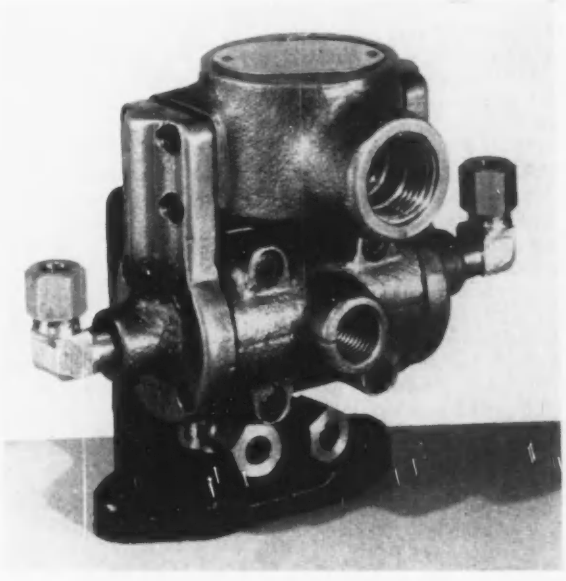
Shown below is a disassembled model EXV 5A electro-air valve. The unit is mounted on an adapter block, and is arranged for remote control operation up to a 3 in. bore conventional air cylinder. The sealed solenoid units are attached to cast bronze and caps. The end caps are drilled to permit switching and ground wires from the solenoid control units to feed into the cast bronze housing.

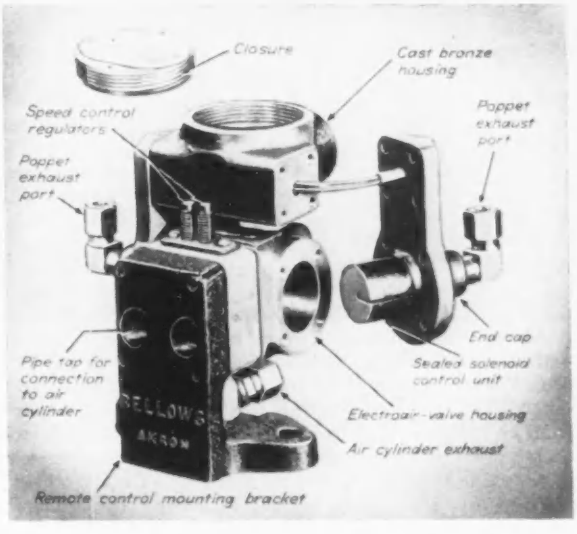
The end caps are also drilled to provide exhaust ports for the air used in shifting the directional valve. These exhaust ports are not to be confused with the air cylinders exhaust ports located under the valve housing. The two speed control regulators give independent speed regulation over advance and retreat strokes of the air cylinder. Separate speed control valves are not required.

The switching and ground leads from the two sealed solenoid control units are attached to a terminal strip in the cast housing. Also, the two leads from a remote control start-stop switch are carried through electrical conduit and attached to the terminal strip. The threaded closure, seats against a machined lip, giving a positive seal.

The valve power is said to be high in proportion to its load. In the $\frac{1}{4}$ in. port size valve, operating at 100 psi line pressure, seventy pounds of live air pressure is available to shift a slide valve requiring only 9 lb. of force to overcome its starting inertia. The large ratio of power to load remains about the same in all valve sizes and at all pressures from 5 to 150 psi. Despite this power, the light weight piston is effectively air cushioned at the end of its stroke.

By using low voltage at the valve, the special transformers (110-220-440 volts primary, 8 v secondary) can be placed in remote locations. The low current required for operation (6 w at 8 v) can be brought to it by any 3 wire rubber covered cable. In addition, the use of low voltage permits sealing of the solenoid against damage, and allows them to be placed in the expanding air stream. Using only 6 w of current, and that only intermittently, continuous high speed operation will not raise enough temperature to feel.





Independent speed controls for precision adjustment of piston rod speed in either or both directions are an integral part of the valve. These speed controls can be quickly adjusted to give an unlimited range of speed control to piston travel; out fast, back slow; out slow, back fast.

The Bellows Co., 230-236 W. Market St., Akron 9, Ohio

CONTINUED ON PAGE 202

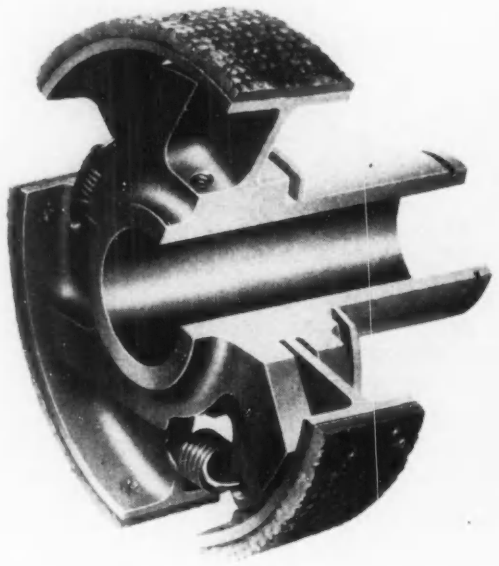
Self-Energizing Centrifugal Clutch

Designed to give maximum efficiency of any gasoline engine or electric motor fwherever load-starting requires a large initial torque, a new self-energizing clutch causes normal speed of the motor or engine to be reached before any load is applied. Then, automatically, the load is picked up. Stalls, or slowdowns below normal operating speeds that occur through overloads are said to be eliminated. The clutch automatically disengages when the engine or motor speed is reduced for idling.

Chatter is also eliminated, and there is a positive release of the clutch through the movement of the shoe outward and rearward. When the motor or engine speed increases to the extent that it exceeds the tension of the clutch springs, a predetermined speed, engagement of the drum is made at a point to the rear of the direct central impact point. Engagement speed is controlled by springs which are interchangeable.

Simplification of design, and fewer than five moving parts, reduces the possibility of any maintenance problems. The clutch is made in four standard models, with various pulleys available. The sizes are: model 100, ½ to 3½ hp; model 200, 3 to 8 hp; model 300, 6 to 12 hp; model 400, 12 to 25 horsepower. Special applications can be made for any unit.

Elgin Sweeper Co., Clutch Div., 6 Oak St., Elgin, Ill.



New Recording Counter-Chronograph

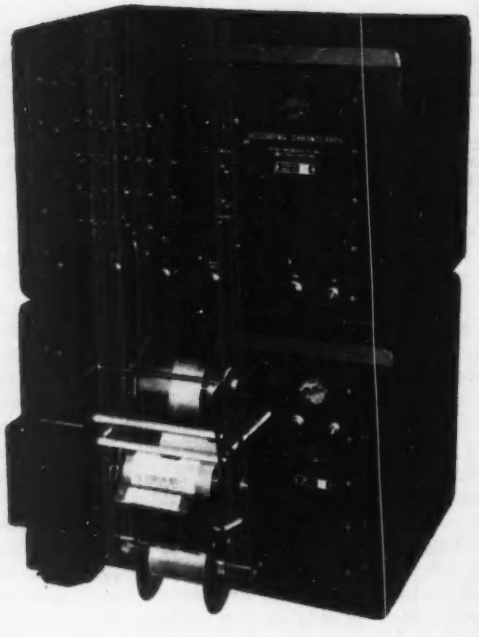
Using a combination of equipment, a recording counter-chronograph completes and automatically records a rapid series of measurements such as individual velocities in a machine gun burst. The data in digital form is transferred by a direct process to electrically sensitive paper, visible for study.

This recording counter-chronograph totalizes elapsed time in steps of ten microseconds or less. The completed measurement is recorded on a continuous roll of teledeltos paper by means of a bank of stylii. Each stylus corresponds to a lamp in the 1-2-4-8 readout. The black traces left on the paper when appropriate stylii are energized momentarily, are read in the same manner as the readout lamps.

As many as 150 measurements per sec can be recorded with a capacity of six digits for each. With fewer digits, certain stylii may be used for timing or other reference points. The 500 ft paper rolls may be driven at any rate from 2½ in. to 20 in. per sec, registering a well-defined dot at low speed which becomes elongated as the rate of travel increases. The paper is indexed intermittently after each measurement is recorded, merging into a continuous drive when the recording rate exceeds twenty per second.

The recording counter-chronograph may be used in the fields of ballistics, frequency-measurement, telemetering, geophysical measurements, aerodynamics and wherever microsecond precision is necessary.

By modification, the teledeltos recorder may be coupled as an accessory to any electronic counter, scaler, chronograph or frequency-time counter made by this company to give the same digital capacity and recording rate. More information may be obtained from the manufacturer.



Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.

CONTINUED ON PAGE 204

Everyone's finding...it's PRP "O" RINGS for top quality, long life and economy!

These advertisements show only a few of the thousands of successful PRP "O" Ring applications. Everyone is finding PRP "O" Rings the best answer to many sealing problems . . . and they are finding, too, that PRP leads the field in engineering help and proper deliveries to keep production lines going. Let us work with you. Send for our "O" Ring Handbook and let us have your inquiries.

Precision Rubber Products
CORPORATION
The "O" Ring Specialists
Dept. 3, Oakridge Drive, Dayton 7, Ohio

Vickers Model PFA2 | Vickers Model PFA3Z-2 | Vickers Model PFA3Y-2

Small, Constant Displacement, Piston Type Pumps

Three fixed displacement hydraulic pumps recently put in production, are of the two and three gallon sizes at 1,500 rpm, rated at 3,000 psi, and have AN approval. Known as the PFA 2, PFA 3Y-2, and the PFA3Z-2, the latter two models differ only in the type of mounting pad used, and are just over six inches in length.

Volumetric efficiency is 96 percent, and overall efficiency is 92 percent. The volumetric efficiency increases as the pressure is reduced. Small size and high horsepower to weight ratio at rated loads and speeds are some of the important characteristics of these accessories. The PFA2 generates 1.9 hp per pound of weight. Pressure pulsations generated by the pumps are negligible. This feature plus quiet operation is made possible by the use of a metered valve plate. Weight for the PFA 2, is about 5.1 pounds.

The mounting position of the pump is unrestricted. The inlet and outlet connections are dependent upon direction of rotation for which the pump is assembled. By turning the connection cover valve plate 180 deg, the position of the inlet and outlet are changed, and the pump may be used for counter-clockwise shaft rotation. The theoretical displacement for the models PFA3Y-2 and PFA3Z-2 is 0.507 cu in. per revolution. The minimum recommended inlet pressure varies from 15 psi absolute at 3,280 rpm to 25 psi absolute at 4,920 rpm. Approximate weight of both models is 8.6 pounds.

The design life of the AN pumps has been increased about 40 percent over the older models. This is said to give improved service performance in the field. The AN approved pumps were designed with straight thread female fittings per specification AND-10050. To make the new pumps interchangeable with older models, they can be fitted with special valve plates having different fittings.

Vickers Inc., 1400 Oakman Blvd., Detroit 32, Mich.

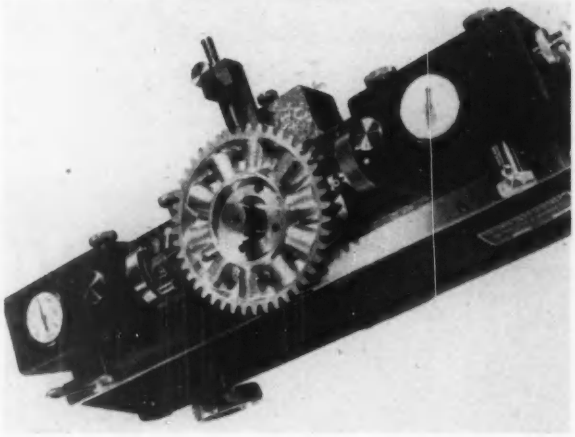
Helix Adaptor Used on Gear Checker

An adaptor and an attachment have been developed for use on a gear checker making it possible to use the checker in every stage of production from the blank to the finished gear, improving quality, reducing scrap, and speeding production.

The new adaptor is said to simplify the set-up for checking the helix angle to the point of almost eliminating the mathematical computations. The size gage block required for the set-up is determined by taking the sine of the helix from the trigonometry table, subtracting one-half the diameter of the adaptor pin, and adding the net result to the constant, which is etched on the machine.

A new rolling attachment for use with master gear makes possible the rapid check of pitch diameter and concentricity accurate to 0.0001 inch. With this attachment, backlash can also be checked with mating gears or master gears.

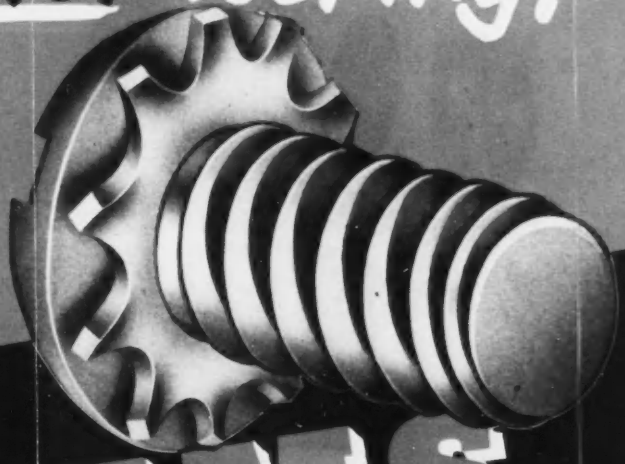
Among the other operations it performs accurately is: checking concentricity without a master; parallelism; backlash; root diameter; crown on face of tooth; tooth to tooth spacing; and accumulated error at 90 or 180 degrees.



Orlandi Gear & Machine Co., 16195 Meyers Rd., Detroit 27, Mich.

CONTINUED ON PAGE 206

faster assembly! better locking!



SEMS
— by —
SHAKEPROOF

the modern *pre-assembled* fastener unit!

FEATURING THE FAMOUS
TRIPLE-ACTION SHAKEPROOF® LOCK WASHERS!

External
Internal
Combination

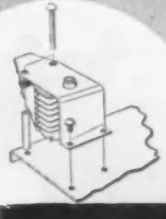
Because there is only one unit to handle, SEMS-by-SHAKEPROOF definitely save assembly time and reduce costs. And they're sure to fasten better, too, because each screw is equipped with a SHAKEPROOF Lock Washer—specially designed for pre-assembly. The teeth of each washer have greater locking contact with the head of the screw and the two parts are always correctly matched for type, size and finish. Investigate SEMS-by-SHAKEPROOF now!

AUTOMOTIVE

As in this power take-off assembly, SEMS are widely used in the automotive industry to resist vibration loosening. And because one part replaces two, handling is faster—driving is easier.

APPLIANCE

SEMS are ideal for use in almost every type of appliance assembly to protect performance. With SEMS, shown here holding a vacuum cleaner skid-runner in place, every screw is locked tight!



RADIO-TELEVISION

In addition to tighter fastenings and lower production costs in the electronics industry, SEMS assure efficient electrical grounding of all components. Here they are used in a condenser assembly.

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Complete engineering data, ordering information and application suggestions make it easy for you to save with SEMS. SEND FOR YOUR COPY TODAY!

SHAKEPROOF inc.

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DIVISION OF ILLINOIS TOOL WORKS

St. Charles Road, Elgin, Illinois
In Canada: Canada Illinois Tools Ltd., Toronto, Ont.

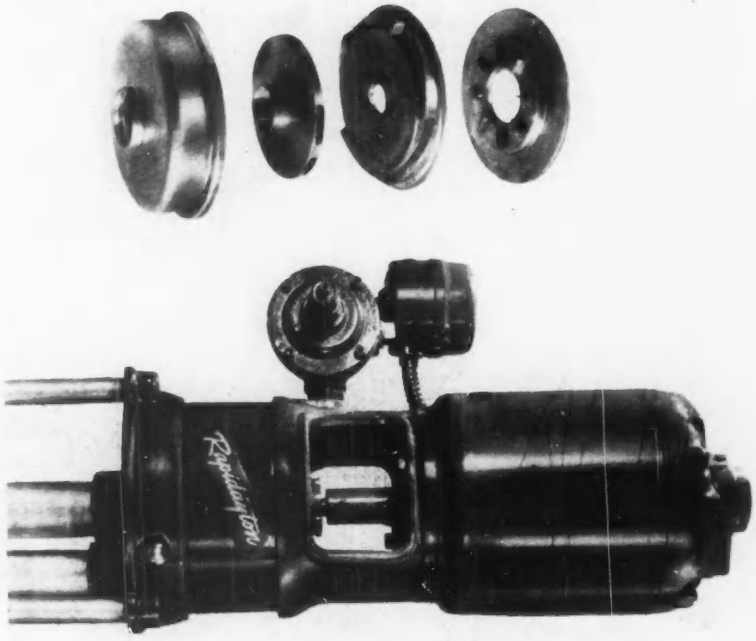
Axial Flow, Multi-Stage Electric Pump

Using the axial flow principle, this multi-stage electric pump is said to be up to 20 percent more efficient than other pumps of similar horsepower.

In addition to the axial flow principle, multi-stage diffusers of brass (or steel) instead of the customary iron castings have been designed. Since all water passages are smooth, frictional loss is reduced and more water per horsepower is produced. Also, the separate castings in which the impellers are usually housed have been eliminated. The new pump case is made of heavy steel, in one piece.

Other advantages of the new pump include an adapter flange for suction and drive lines, making it easier to fasted the pump on the pipes. The pump has a cartridge-type seal which can be replaced without disassembling the pump or disturbing the piping.

Known as the super multi-stage vertical pumps, the models for deep wells (up to 200 ft) will be equipped with jet assemblies, and with standard NEMA motors ranging in size from $\frac{1}{2}$ to 2 hp. The shallow well pumps will be available with from $\frac{3}{4}$ to 2 horsepower standard motors.

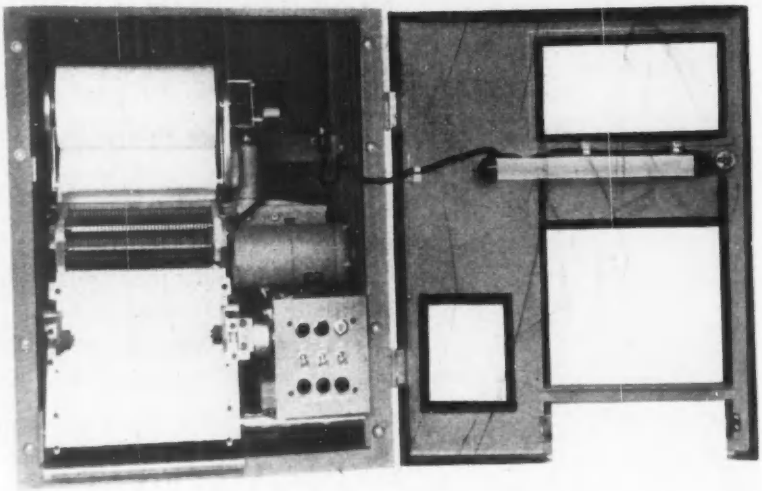


Dayton Pump & Mfg. Co., 500 N. Webster St., Dayton, Ohio

High Speed Printer for Digital Computers

The synchroprinter is a high speed printer developed for recording the output of analog or digital computers in directly readable form on standard paper. It may be used in any application where data is available in electrical or mechanical form. It is capable of printing fifteen lines of forty characters each in one second, or a rate of 600 characters per second. Printing is accomplished by continuously rotating type wheels and cooperating print hammers. It is possible to have simultaneous decimal printing of forty channels, or sequential printing of information from one channel on one line.

The print roll has 40 rings of ten characters each, engraved on its periphery. As the print roll rotates, the timing sync generator sends out a pulse each time a new row of 40 digits is in the print position, therefore, ten timing pulses are generated during every revolution of the print roll. The other sync generator produces a single pulse per revolution which is used to determine the beginning of the printing cycle and may be used for controlling ancillary equipment.



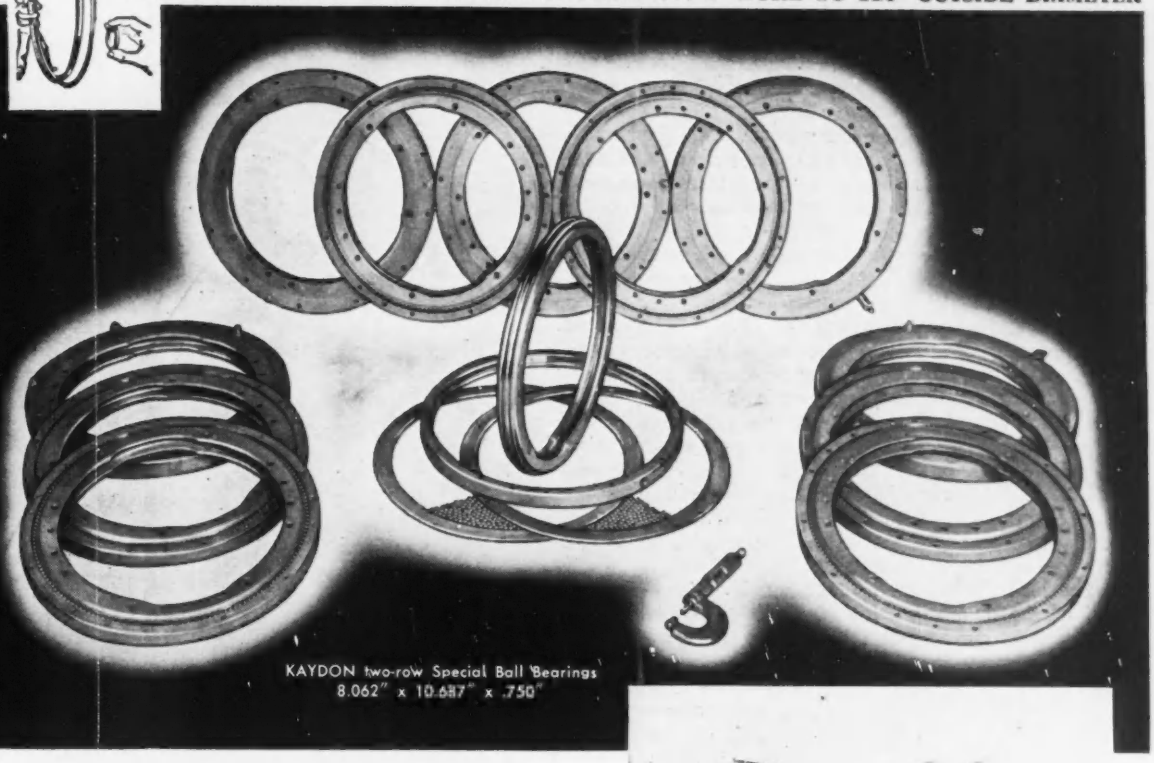
The measurements of the high speed printer are: 19 in. wide, 15 in. deep and 24 in. high.

Anelex Corp., Concord, New Hampshire

CONTINUED ON PAGE 208

Contact KAYDON of Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



KAYDON two-row Special Ball Bearings
8.062" x 10.687" x .750"

Dependable Life-Savers ...KAYDON-bearinged Piasecki HELICOPTERS

CONTROL movements of Piasecki HUP Helicopters . . . life-savers of the air . . . are transmitted to the spinning rotor blade assemblies by means of a swash plate that moves on unique two-row **KAYDON** Special Ball Bearings.

Control of the helicopter is obtained by the movement of its rotor blades. Each blade can move in six different directions while they are rotating. Thus the mechanism responsible for control movements is complex, important, and it demands the utmost in bearing-precision.

KAYDON met the challenge of this intricate bearing-problem with these special two-row, thin section, 8.062" x 10.687" x .750" ball bearings. Similarly, **KAYDON** cooperates with designers of many types of precision equipment to achieve their objectives.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

Portable Hydraulic Tester for Small Parts

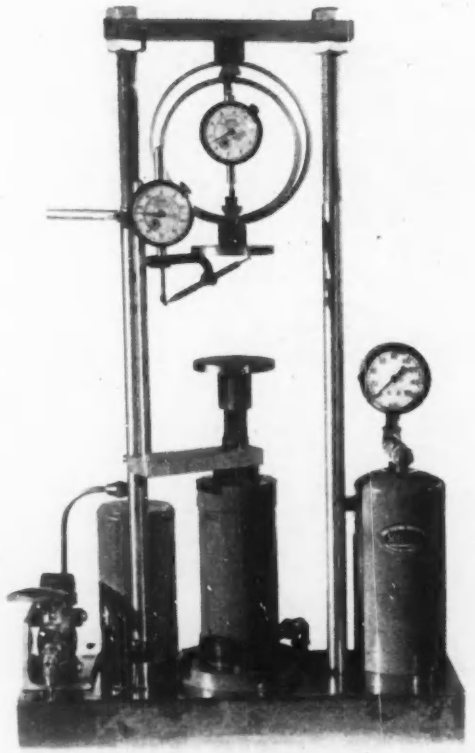
Accurate compression and crushing tests are possible with this lightweight, low-cost, portable hydraulic compression machine, said to be an effective testing apparatus for many types of small parts. It has been used with good results on metal, ceramic, wood, and plastic parts; on paper boxes and other containers, and on soils, springs, and similar materials. It also may be used on inspection lines and in industrial laboratories.

In this machine the load is applied to the test specimen through a hydraulic system actuated by compressed air. When connected to an air source, it is ready for testing, and no warm-up period is required. The load applied to the specimen is indicated on the dial of a double proving ring. This double proving ring is used to give greater accuracy in the low range in tests involving large loads, and will eliminate the necessity of changing rings for different tests. When the capacity of the more sensitive outer ring is reached, the heavier inside ring is brought into action. This method permits taking advantage of the higher sensitivity of the outer ring without danger of overloading. The low range of the double proving ring is sensitive to loads of 0.1 pounds.

The load applied to the specimen is indicated on the dial of the double proving ring. It is possible to get complete stress-strain data by reading the proving ring dial and the specimen strain dial at intervals during the test. A feature of the machine is its ability to release the load at any time during the test, or at the point of failure, keeping the specimen intact for any measurements, photographs, drying or other requirements.

The tester weighs approximately 30 pounds. Dimensions are 6 in. by 16 in. by 26 in. high. Standard test platens will accommodate specimens up to 4 in. in diameter and 6 in. high.

The standard model has a capacity of 350 lb under an operating air pressure of 100 psi, but machines with capacities up to 1,000 lb can be supplied. A lightweight air storage tank with carrying handles is available for use in field laboratories or in places where there is no regular air supply. One filling will run 50 tests.



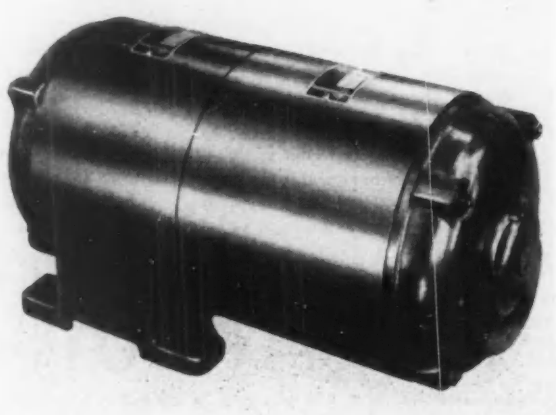
Labquip Corp., 4520 W. North Ave., Chicago 39, Ill.

High Frequency Power Supply

Meeting AN-E-19 requirements for power supplies, a new 400 cycle motor-alternator uses no rotating coils, requires no brushes or springs, and is small in size. The laminated rotor is mounted in ball-bearings, said to be practically wear-free. There are no other moving parts.

Total size measures approximately 22 in. x 12 in. x 12 in., weight approximately 125 pounds. Because of its small size, the motor-alternator is portable and may be moved to any work location. Outputs are furnished in wattages up to 1,000, single phase, or 1,800 three-phase. With single or three-phase common-shaft motor drives.

Because of the shape of the inductor, the skew of the inductor laminations, and other design considerations, a pure wave form results; less than 5 percent total harmonic content exists. Voltage regulation is ±1 percent. Output voltage: 115 single phase, 115/200 three phase.



American Electric Motors, 4811 Telegraph Rd., Los Angeles 22, Calif.

CONTINUED ON PAGE 210

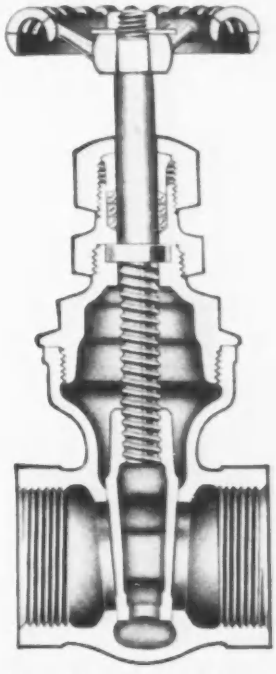
For quicker answers to piping problems

Go to your CRANE Catalog

Crane offers the world's most complete line of piping equipment. But suppose your design requires a certain brass gate valve of unusual ruggedness. How would you find it?

Simply reach for your Crane Catalog and turn to the listing of brass gate valves in the index—pages 13 to 21. A quick rundown of service recommendations shows that No. 437 on page 17 is the valve you're after. And right there are all the facts you need—sizes, dimensions, pressure and temperature ratings, plus complete design, material and construction details.

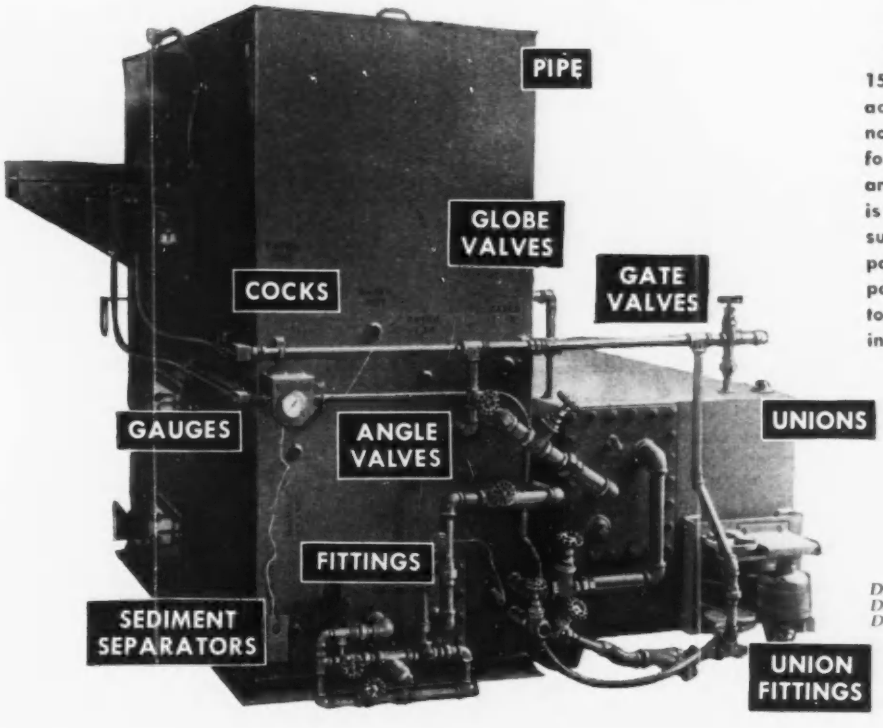
Yes, your Crane Catalog is a real time-saver when writing specs. But, more important, when you specify Crane piping equipment, you specify recognized quality that pays off in terms of customer acceptance and satisfaction through the years.



UNUSUALLY RUGGED

150-Pound Brass Gate Valve with accurately guided wedge disc, non-rising stem. Recommended for service on steam, water, oil and gas lines where extra strength is required. Tight stem seal assured by high quality stuffing box packing and gland; can be repacked under pressure. Sizes ¼ to 3-inch. Also available with rising stem, screwed or flanged ends.

LOOK TO THE BROAD CRANE LINE FOR ALL YOUR PIPING EQUIPMENT NEEDS



DETREX Steam-heated Gyro Degreaser by Detrex Corporation, Detroit, Michigan.

The Complete Crane Line Meets All Your Valve Needs. That's Why—
More Crane Valves Are Used Than Any Other Make!

CRANE.VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

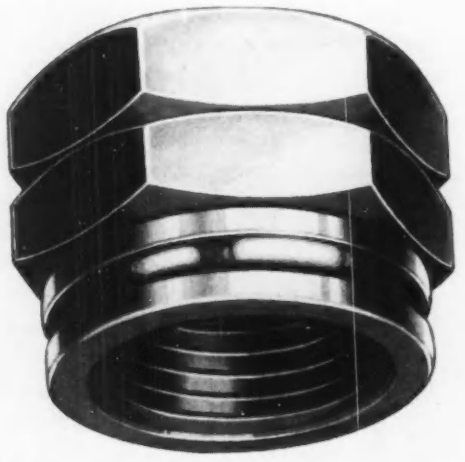
VALVES • FITTINGS • PIPE • PLUMBING • HEATING

Free-Running, Self-Energizing Locknut

A seating type, all metal, free-running, self-energizing locknut that is usable over and over, is manufactured in various materials, and will withstand temperatures up to 1,600 F without thread seizure.

The grooved washer at the bottom of the nut is pressed over the threaded section suspended from the main body of the nut. The nut spins freely on the bolt down to the work. After the proper torque has been applied, the washer compresses, causing the threaded section inside the washer to move in and lock radially on the bolt. When the threaded section inside the washer picks up all the load it can carry, it elongates a few thousandths of an inch permitting the bulk of the load to move up into the main body of the nut. This reduces the high stress concentration and torsional load normally found in the first three threads in the nut and bolt, permitting more wrench torque to be applied before exceeding the elasticity in the bolt.

Locknuts are available in thread sizes from 10-32 to one inch-14. Available in stainless steel and other alloys.



Klincher Locknut Corp., 2153 Hillside Ave., Indianapolis, Ind.

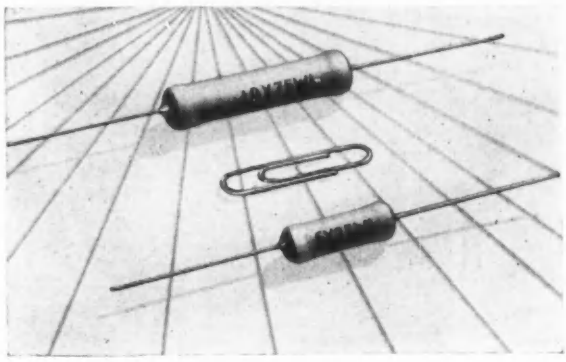
Space-Saving Miniature Power Resistors

New miniature power type resistors with axial leads, trade named Axiohm, have been developed for use in radio, electronic and other equipment where space saving and minimum assembly costs are essential.

These resistors are made with special alloy resistance wire of low temperature coefficient of resistivity and wound on tough miniature ceramic cores. No. 20 B.&S. tinned axial leads are mechanically anchored and silver brazed to end caps. Although the assembly is encased in vitrohm enamel, forming a hard, heat conducting hermetic seal, the axiohms are not classified as insulated type resistors.

Features of the resistors include: space-saving design; self-supporting; no lugs, bolts or brackets needed for mounting; axial leads permanently anchored in place and are not tin-dipped for easy sodering; vitrohm construction.

The resistors are available in 5 and 10 w sizes. These free air ratings are based on a 540 F hot spot temperature in an ambient temperature not exceeding 104 F. Resistance tolerance is ±10 percent. Lower tolerances are available.



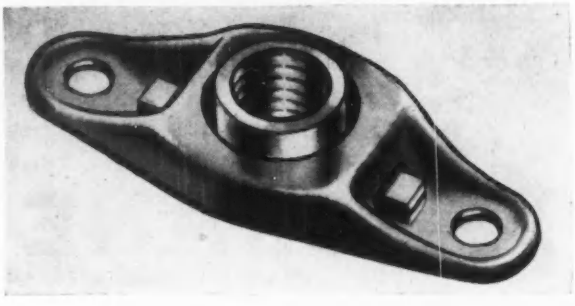
Length of the 5 w resistor without leads is 1 in., dia, 11/32 inch. The 10 w unit measures $1\frac{3}{4}$ in. with a $\frac{13}{32}$ in. diameter.

Ward Leonard Electric Co., Mt. Vernon, N. Y.

Light Weight, Self-Locking, Floating Anchor Nut

This new, light weight, self-locking nut, known as a floating anchor nut, said to incorporate a new principle of design, consists of an assembly of two parts: a threaded nut portion, and a retaining shell. This gives a 1/16 in. radial movement between the nut and the anchoring portion. Both parts are formed of light gage annealed spring steel, and are spring tempered to give a light-weight, yet rigid fastening device. The float, a lateral movement between the nut and the anchored retaining shell, aids in the alignment of the nut and bolt in the assembly. The nuts are cadmium plated, and may be used in temperatures up to 550 Fahrenheit.

Kaynar Mfg. Co., 820 E. 16 St., Los Angeles, Calif.



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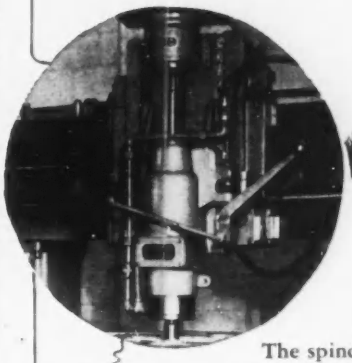
How "ABUSE CAPACITY" is built into a 12 speed spindle



The spindle of Pratt & Whitney's 40" Vertical Profiler and Miller is designed for 12 operating speed ranges from 260 to 6200 r.p.m. Machine operations may be confined to continuous production at any one speed for extended periods. The diversification of operating conditions represented puts an extremely heavy burden on spindle bearings.

"Abuse capacity" is provided by the aristocrats of all bearings . . . Fafnir Super-Precision ball bearings. Four pairs support the main spindle and drive shaft. Notice how they are arranged in the cross section diagram. This set-up not only assures positive axial and radial rigidity, but also provides for shaft expansion. The bearings run cool under varying conditions of load and speed . . . conserve power . . . need no adjustment . . . and are permanently grease packed.

Whatever your bearing problem, a few minutes spent with a Fafnir representative may help you solve it as successfully. The Fafnir Bearing Company, New Britain, Conn.

Bearings used
Fafnir Super-Precision Ball Bearings made to extremely close tolerances, assuring accuracy and smoothness of operation . . . counterbore construction with shallow shoulder on one side . . . one-piece, composition retainers.

FAFNIR
BALL BEARINGS

MOST COMPLETE LINE IN AMERICA

Proportioning Indicating Pyrometric Controller

The model JP proportioning indicating pyrometric controller, so called because it automatically adjusts the ratio of power on and off over a given time-cycle to maintain any desired temperature set with the index pointer, has been developed for use with plastic injection molding machines, chemical and refining plants, the packaging industry, extruding and industrial heat treating fields, and other processes where it is necessary for exact temperatures to be maintained.

This straightening out of the temperature control curve is said to give a closer and more accurate control. The proportioning controller anticipates and corrects for thermal inertia by preventing control point overshooting on most installations, with a subsequent improvement in production and lowering of operating costs.

The operation of a proportioning controller over an on-off controller is shown by the comparison of the temperature graphs of the two instruments. With the on-off controller, the temperature oscillates back and forth at the set control point, and control action is accomplished by the rise and fall of the actual indicated temperature. The proportioning controller anticipates temperature changes of its loads, eliminating the lag or thermal inertia of both the heating and cooling cycle. This gives a straight line control at any precise temperature setting. It also automatically determines the percentage of time the system requires heating and the percentage of time the fuel or power input should be turned off to maintain the desired preset temperature.

One of the features of the model JP controller is that the meter pointer indicates the accurate temperature at all times, because the proportioning action takes place in the controller section of the circuit, and does not affect the reading of the temperature indicating pointer.

The model JP pyrometric controller is available in 36 standard scale and thermocouple ranges and is powered from either 115 v or 230 v, 60 cycle lines.

Taco West Corp., 525 N. Noble St., Chicago, Ill.

New High Gain Preamplifier

A new high gain a-c preamplifier, designed to permit the extension of the measurable range of graphic recording instruments or cathode ray oscilloscope into the microvolt region, maintains a relatively flat frequency response from 0.2 to 400 cps.

Designed as the model BL-954, the instrument was designed for use with the magnetic direct writing oscillographs, made by this company, and medium or low gain amplifiers, to permit permanent records of measurements of electrical phenomena in the microvolt region such as brain, heart and nerve potentials, or research and industrial laboratory measurements.

Voltage gain of the instrument is 200,000 times when operated push pull, and when used with the direct writing oscillographs and amplifiers made by this company, it is sufficient to give one millimeter of pen deflection on the oscillograph chart per 2.5 microvolts input. The dry "B" batteries are mounted in the carrying case, while either external-storage or dry batteries may furnish "A" power.

Bruih Development Co., Instrument Div., 3405 Perkins Ave., Cleveland 14, Ohio

CONTINUED ON PAGE 215

DIE CASTING

assures peak performance when "the heat's on"!

CASE HISTORIES FROM MT. VERNON FILES

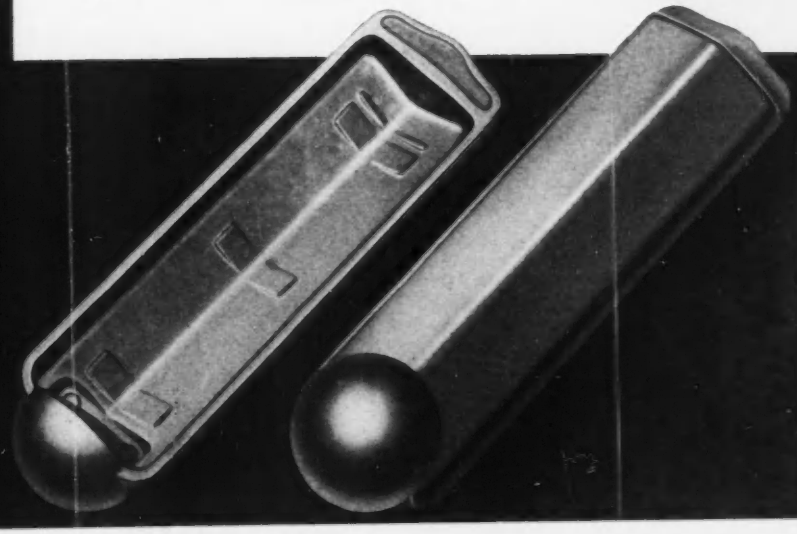
Die casting is industry's high speed producer. Not only simple parts, but really difficult ones are "naturals" for the die casting process —and they are produced fast. Yes, it *pays* to remember die casting when you're long on orders and short on time.

But that's only one angle. Die casting means savings and satisfaction whenever you employ it—actual cutting of production costs, and highly satisfactory products superior in performance and appearance.

Look at this versatile thermometer job. Moeller Industrial Thermometers required a neat-looking housing that could be easily installed in a variety of positions to suit different applications. Provision of a spherically-shaped base, which can be drilled at any angle to accommodate a tubular mount, has solved the design problem. And Mount Vernon die casting handles the production problem—by turning out these V-shaped housings rapidly and accurately; so clean that subsequent machining, other than drilling of mount hole, is unnecessary.

Whether the product you're planning to manufacture is simple or complex, it will profit you to consider die casting—and consult with us. With our long experience, specialized knowledge, and modern facilities we are in an excellent position to help you solve your production problems and give you top quality service.

MT. VERNON
DIE CASTING CORP.
MT VERNON NEW YORK



CONFIRM IT NOW!

While your new product is still on the drawing board . . . that's the best time to check on the special characteristics you need in your pliable parts. Design problems, resistance properties, and physical characteristics can all be confirmed by Sirvene engineers concurrent with the balance of your design development. This Sirvene service saves time for you and assures you of the right part for the job when you do get into production.

All Sirvene parts are custom-developed to meet special sets of operational circumstances. They are produced in quantity with laboratory-like care and precision . . . verifying every performance specification. When you need a unique pliable part . . . that's when you need Sirvene.

CHICAGO RAWHIDE MANUFACTURING CO.
1299 Elston Avenue SIRVENE DIVISION Chicago 22, Illinois

The cooperative research and engineering services which C/R has provided in producing special Sirvene synthetic rubber parts for leading manufacturers, are also available to you. We will be pleased to send you any further information you wish. Brochure on request.

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SIRVENE
SCIENTIFICALLY COMPOUNDED ELASTOMERS

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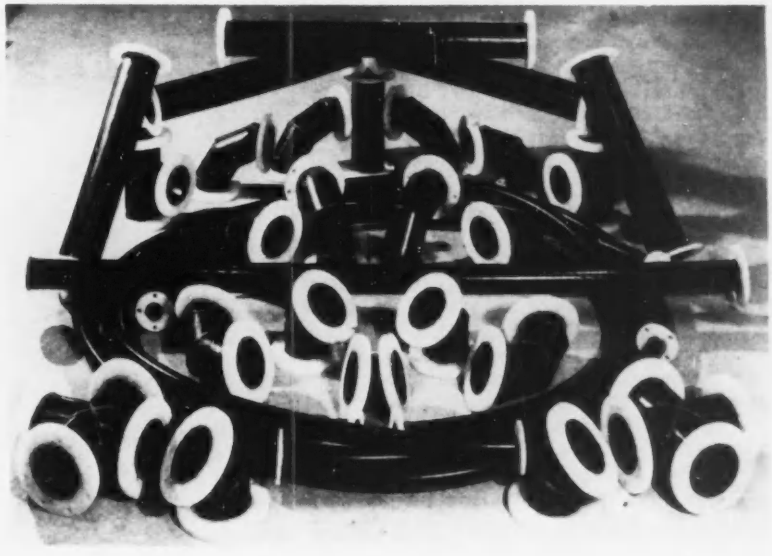
Mechanical Leather Products
Boots, diaphragms, packings and other products give dependable service under difficult operating conditions.

PERFECT Oil Seals

C/R seals are used in more motor vehicles, farm implements and industrial machines than any other shaft-type sealing device.

Representatives in These Principal Cities
Boston • New York • Syracuse
Philadelphia • Pittsburgh • Cincinnati
Cleveland • Detroit • Peoria • Minneapolis
Kansas City • Houston • Los Angeles
San Francisco

Strong, Acid Resistant, Plastic Piping



Resistant to a wide variety of solvents, and unaffected by mineral acids, salts, and alkalies at temperatures up to 150 F, this tough, but semiflexible piping may be used in temperatures as low as —50 F, and retain all its properties through repeated freezing and thawing. It is also free from electrolytic corrosion.

Known as cyclothene pipe, it is made from high purity ingredients, is safe for the transportation of pharmaceutical products, and will not react with any food or beverage. Because it is resistant to chemicals, it is good for sewage and acid drainage use, for fume piping, and for corrosives. Its electrical properties also permit it to be used as conduit.

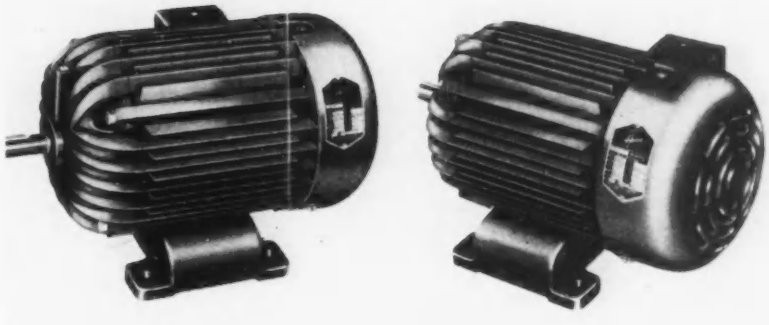
Made in all sizes from ½ in. to 6 in. cyclothene pipe is furnished in stock lengths of 25 ft in 4 in. or larger pipe, 150 ft coils for 3 in. pipe, 250 ft coils for 2 in. pipe, and up to 400 ft in smaller sizes. Because of the long lengths, and because its semi-flexible construction permits bending, installation costs are reduced. A hack saw and screw driver are the only tools required for installation.

Cyclothene pipe may be connected with knurled and insert connectors clamped with stainless steel bands. Where connection to other equipment is required, a standard thread adapter is available; and if necessary, the pipe may be furnished with weld-on flanges in specific lengths. The ells, tees, and ys are fabricated as they are needed.

The physical properties are: ultimate tensile strength, 2000 lb/in.²; yield point, 1300 lb/in.²; elongation, 400-500 percent; impact strength, Isod, 16 ft lb/in.; modulus of elasticity, 17,000-19,000 lb/in.²; Rockwell Hardness, R-scale, 11.

Munray Products Inc.,
12400 Crossburn Ave., Cleveland 11, Ohio

Compact, Totally Enclosed, Fan Cooled Motors



A new series of totally enclosed, and totally enclosed fan-cooled motors ranging from ¼ through 3 hp has been introduced. With compact design being stressed on models in this line, it resulted in more horsepower per pound of motor.

Smaller ratings are totally enclosed. Intermediate ratings built in smooth, field-ring construction are totally enclosed, fan-cooled. Larger ratings are totally enclosed, fan-cooled, but in addition have external fins for greater heat dissipation.

In the Capacitor start motors, in the ¼, ⅓, ½, and ¾ hp ratings, models are available in 1140, 1725, and 3450 rpm in 115/230 volts. The speeds and hp ratings are the same for the Polyphase motors, but the voltages are 208/220/440. Other ratings are 1, 1½, 2, and 3 hp. Speeds for the capacitor motors are 1725 and 3450 rpm. The polyphase motors of the same ratings have speeds of 1140, 1725, and 3450 rpm with the exception of the 2 and 3 hp motors which are available only in the 1725, and 3450 rpm speeds.

The motors are intended for heavy duty, general purpose work. All blind passages that might accumulate dirt have been eliminated. Windings are insulated with heavy formvar and braced with a high grade baked varnish on both fan-cooled models.

Hoover Co., Kingston-Conley Div.,
70 Brook Ave., N. Plainfield, N. J.

CONTINUED ON PAGE 216

General Purpose, Hermetically Sealed Relay

A general-purpose hermetically-sealed relay for use in aircraft, shipboard, and portable land-based electrical systems and electronic equipment has been designed to meet, or better provisions of Joint Military Service Specifications for relays MIL-R-6106. The relay is said to resist harmful atmospheric conditions, including salt spray, high humidity, sand, fungi, and widely varying air pressures. It also conforms with Air Force-Navy Aeronautical Standard AN-3304.

During manufacture, the interior of the relay is exhausted of air, vacuum baked to remove all traces of moisture, filled with dry nitrogen to a pressure of one atmosphere, and then sealed.

Using a new armature and magnet design in the relay is said to give it greater force, or pull. In addition, the use of a glass-reinforced polyester compound for stack insulation increases dielectric strength and arc resistance, and gives greater impact strength.

Other features of the new relay include contact fingers of beryllium copper, which will not anneal even after long exposure to high temperatures, silver contacts that permit high current-carrying and interrupting capacity, a corrosion-resistant enameled enclosure, and a glass-metal header that provides the hermetic seal.

The new relay is a 4-pole, double-throw type, with a contact rating of 3 amp, 28 v d-c, or 115 v a-c. It will withstand instantaneous voltage surges up to 1500 v without failure. The new design is said to give increased reliability. A complete electrical diagram is stamped on the housing.

General Electric Co., Control Dept., Schenectady 1, N. Y.

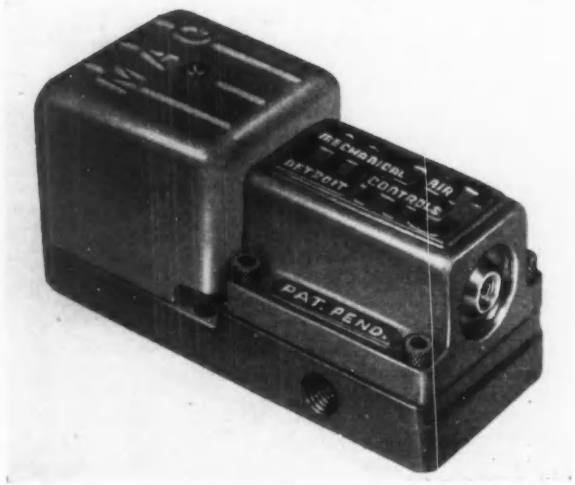
4-Way, Solenoid Operated Air Valve

A ¼ in. 4-way solenoid operated spring return air valve for actuating double acting cylinders, has a full ¼ in. pipe orifice area through the valve, an operation by direct solenoid control, and a spring return of an aluminum spool which is the only moving part in the unit. Small special O-rings mounted on this spool act as seals when they come in contact with the bores of the body and end cap retainers.

These bores are honed, polished, hard chrome plated, and repolished to a mirror finish to give a good contact surface and long life for the two O-ring seals, which are the only wearing parts.

The valve is compact, measuring only 5 in. long, 2½ in. wide, and 2½ in. high. Parts consist of a cast iron base, bronze body and retainers, aluminum spool, and solenoid with aluminum cover. O-rings are used as static seals throughout, and gland type packing is not required. The end cap retainers are held in the body by retaining rings and are easily removed by inserting a 5/16 in. screw in an integral thread of the retainer.

Current requirements of the solenoid are 0.8 amps inrush, and 0.2 amps holding at 115 v, 60 cycle. It is a constant duty type, allowing the solenoid to be held energized for any period of time. The valve is available for any voltage or cycle requirement, and can be mounted in any position. The ¼ in. side base pipe porting is standard, but bottom porting or manifold mounting can be furnished upon request. The exhaust port may be restricted, when necessary, to reduce cylinder piston speeds.



Mechanical Air Controls, 15311 W. 11 Mile Rd., Royal Oak, Mich.

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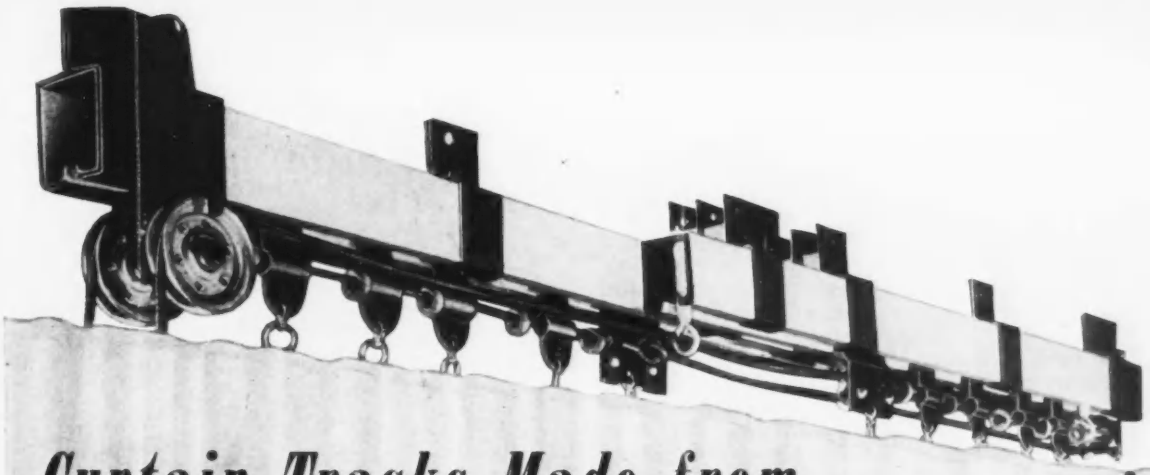


Curtain Tracks Made from Cold-Formed Shapes

Here's a Bethlehem Cold-Formed Shape you're apt to find in modern theatres, studios or school auditoriums. It's a sturdy curtain track, built to carry heavyweight curtains quickly and quietly across a stage.

We form these 14-gage shapes by cold-rolling, and supply them to the manufacturer in any length. The tracks must be one continuous piece, free of any joints except at the center lap. Inside, ball-bearing carriers roll on two smooth, parallel treads.

Curtain tracks are only one example of the growing variety of parts and products made from Bethlehem Cold-Formed Shapes. Manufacturers in widely-separated fields regularly come up with new ideas for these versatile shapes.

Bethlehem Cold-Formed Shapes are produced from steel sheets, strip or plates. Users like their uniform thickness, excellent strength-weight ratio, and relatively scale-free surface. What's more, Cold-Formed Shapes mean lower fabricating costs because they form, weld and assemble so readily. We make them on presses, brakes or rolls in all gages from 5 to 24.

Perhaps there's a place for Bethlehem Cold-Formed Shapes in your business. Why not talk it over with a Bethlehem engineer?

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY

BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

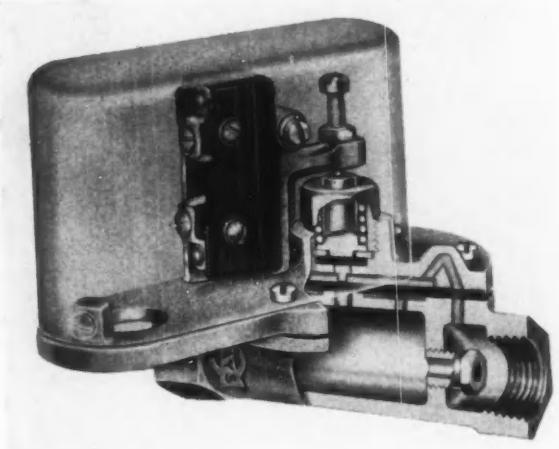
Automatic Interlock Protects Equipment

Known as the shur-flo automatic interlock, this device operates an electrical control switch which makes equipment inoperative, or operates an alarm when the flow of water, air, or light oil in the supply lines drop below operating efficiency. This prevents any possible damage to the equipment.

The automatic interlock is made in two types, one of which shuts off the operation when the fluid flow falls below a required predetermined minimum, and the other when the supply exceeds a given maximum rate of flow.

The shur-flo operates on a differential of flow pressure across a nozzle. The electric switch on the shur-flo makes or breaks contact according to the movement of the lever arm and plunger that transmits the diaphragm action to the switch. A protective strainer is not required for efficient operation of the switch. It may be connected to prevent the use of equipment or with an alarm signal to give warning that attention is needed.

Among the applications of the automatic interlock are: protection of fluid-cooled industrial controls such as tubes and transformers; guarding fluid-cooled industrial equipment such as air compressors, condensers, humidifiers, and welding machines; maintaining the coolant supply to bearings, and other units; automatic operation of electric garbage disposal and similar equipment.



Hays Mfg. Co., 12th and Poplar Sts., Erie, Pa.

"Donut" Instrument Current Tranformers

Designed for larger inside diameters of "donut" instrument current transformers for use with inserted primaries, a new line of transformers, known as the model 321 series, has been developed having a maximum O.D. of 5 in.; a minimum I.D. of 2.25 in.; and a maximum thickness of 1.75 inches. Capacity is 2.5 v ampere. Accuracy is 1.2 percent at full rated capacity. Frequency is 25 to 133 cycles.

These transformers are primarily intended for use with ammeters, relays, or other devices where phase angle is not important. The phase angle error is between zero and +2 deg, depending on the ratio and working current. They can be used with wattmeters where such an error is not important to the readings obtained.

These transformers are insulated for use on 2,400 v rms service. For additional protection the inserted primary should be insulated to withstand normal and transient breakdown potentials. Leads normally supplied are two feet long, with $\frac{1}{4}$ in. soder lugs. Leads are color coded.

Ratios available are : 1000/5; 1200/5; 1500/5; 2000/5; 2500/5; 1000-2000/5. All ratios are one primary turn.

Associated Research Inc., 3758 West Belmont Ave., Chicago 18, Ill.

A NEW MINIATURE CRYSTAL TEMPERATURE CONTROL OVEN, the JKO-2T, has been developed for crystal units normally in the frequency range of 16 kc to 200 kc. This unit will give temperature stabilization at 75 C, ±2 C for one or two of the H-7T crystal units in ambients from −55 to +70 C also made by this company. It has a standard octal base; diameter 1.28 in.; height, 2.41 inches. Heater, 6.3 v a-c or d-c at about 1.40 amperes. The James Knight Co., Sandwich, Ill.

A HERMETICALLY SEALED RUNNING TIME METER registers the operating time of machine tools, electronic, electrical and general industrial equipment. Sealed in a drawn steel case, the meter is tamper-proof, and will operate in a wide range of temperatures, and in hazardous atmospheres. It registers in 1/10 hour steps to 9999.9 or hour steps to 99999. It takes no more space than a 3½ in. meter. Marion Electrical Instrument Co., 401 Canal St., Manchester, N. H.

CONTINUED ON PAGE 220

. . . to make a model . . .

. . . or move a mountain

. . . let *Lamson* fill your Fastener needs

As one of the few "full line" fastener manufacturers, Lamson can greatly simplify your fastener procurement. For they can supply practically any type or size of bolt, nut or screw plus many special fastening devices such as wire rope clips, cotters and threaded studs.

So if you are now using one or more Lamson fasteners, consider the advantage to you of making Lamson & Sessions headquarters for *all* your fastener needs. It will simplify ordering, speed delivery and save you money in terms of clerical and billing time.

Lamson & Sessions

The LAMSON & SESSIONS Co.
1971 West 85th St. • Cleveland 2, Ohio
Plants at Cleveland and Kent, Ohio • Birmingham • Chicago

Check the products below that interest you; tear off bottom of ad and send to us for complete information.

HI-TENSILE CAP SCREWS
"1035" Heat Treated Steel.

LOCK NUTS
Economical, vibration proof. Can be used repeatedly.

LOCK THREAD STUDS
Thread locks and seals in standard tapped holes.

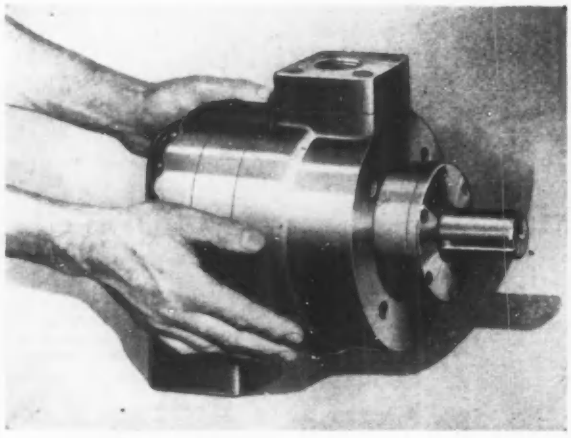
CARRIAGE AND MACHINE BOLTS
Cut or rolled threads American Standard Heads.

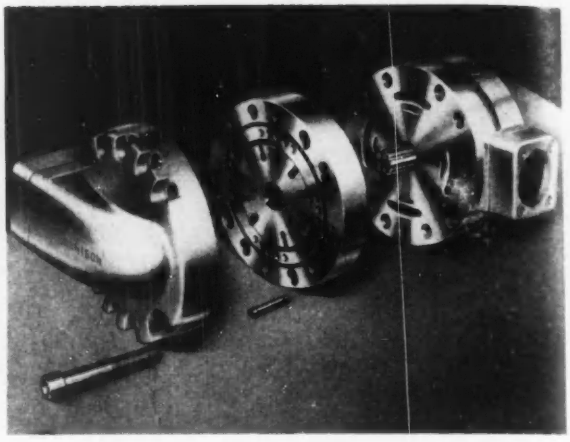
SQUARE AND HEX MACHINE SCREW NUTS
Semi-finished, hot pressed, cold punched.

MACHINE AND TAPPING SCREWS
Precision made for fast, economical assembly.

COTTER PINS
Steel, brass, aluminum and stainless steel.

"BENT BOLTS"
Including U bolts, eye bolts, hook bolts, etc.





2,000 Psi Vane Type Pump-Motor Combination

The design of a new 2,000 psi vane type oil hydraulic pump that may be used as a fluid motor, is of single stage, and is said to contain a new principle of radial balance and construction. No alterations are necessary, within the unit itself, to make use of its two-way operation. The unit may be used in clockwise or counter-clockwise rotation, for both pump and motor operation. Direction of rotation, in any application, can be reversed by means of a change in position of the pumping cartridge.

Four sizes are available, and in each size a choice of cam rings is available, to widen the range of oil delivery or torque ratings. This gives a range of eight models of different capacity levels. In pump applications, these capacities range from 2½ to 60 gpm maximums; in fluid motor use, regardless of direction of rotation capacities range from 12 to 257-in.-lb of torque per 100 psi.

The unit is designed to give constant displacement and pulsation-free action under all operating conditions. The vanes in the unit feature dual sealing edges that give better valving action at the point of exhaust. Getting complete hydraulic balance within the unit helps to reduce wear, and gives longer maintenance-free service.

The exploded view of the new pump-motor, shows the simplified, three part construction. The porting blocks can be used interchangeably as either suction or pressure ports, or as inlet and outlet ports in motor applications.

Denison Engineering Co.,
1171 *Dublin Rd., Columbus* 16, *Ohio*

Springs Aid Action of Air Control Valves

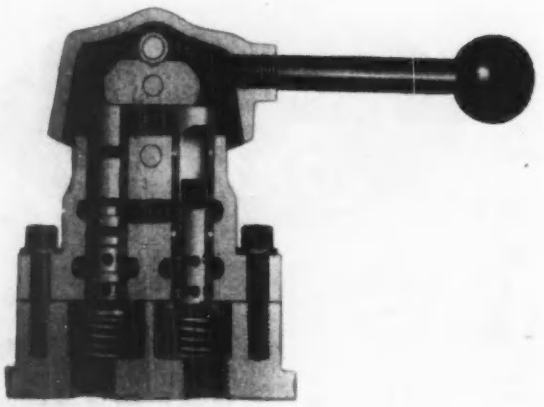
The neutral position of the lever on a line of air control valves is maintained by two light springs located directly underneath the lower poppets, thus giving a faster and trouble-free action. The lower seats are made of a molded oil-resistant and high impact-resistant material.

Three types of rockers are available: locking, non-locking, and a combination of the two. The locking rocker, because of its design, is pressure-locked in the engaged position. Rockers are interchangeable and can be installed in a few minutes without disturbing the valve installation.

All pins, rollers and rockers, as well as the upper wearing surface of upper poppets, which are in contact with the rockers, are hardened to give longer life. The entire mechanism is completely shielded by a high tensile manganese casting.

The lower poppets are made of a high tensile brass and are enclosed in a bronze housing. All working parts can be replaced without the use of special tools, by removing the bronze housing from a separate base casting. Because of this design, the piping to the valve is not distributed.

With the handle in neutral position, both poppets are closed to pressure and open to exhaust so the cylinder is static without pressure at either end. Valves can be



supplied with either vertical or horizontal handles, and with side or bottom ports bases.

Numatics, McLeod Ave., Milford, Michigan

CONTINUED ON PAGE 222

Koppers expands service on American Hammered

Industrial and Aircraft Piston Rings

BECAUSE of the sale of its automotive replacement piston ring business Koppers now is in a position to further increase its leadership in piston and sealing rings for aircraft, general industrial, marine, commercial engine, railroad and oil field applications.

To present and prospective users of Koppers American Hammered Industrial Rings, this means increased engineering service, through concentrated attention to the solution of industrial and aviation ring problems; and greater production capacity for both original equipment and replacement rings. Our available manufacturing facilities include:

A large foundry equipped for both static and centrifugal casting . . . a modern heat-treating plant . . . one of the largest and most up-to-date chromium plating plants . . . modern machine shops . . . an efficient engine test laboratory . . . a modern and complete piston ring research laboratory.

In industrial and aviation rings, American Hammered *means* Koppers . . . builders of *engineered* products for industry.

Write, wire or phone us for the right answer to your piston or sealing ring problems, today. KOPPERS COMPANY, INC., *Piston Ring Department*, 1496 Hamburg Street, Baltimore 3, Maryland.

KOPPERS

Koppers American Hammered Industrial Piston Rings

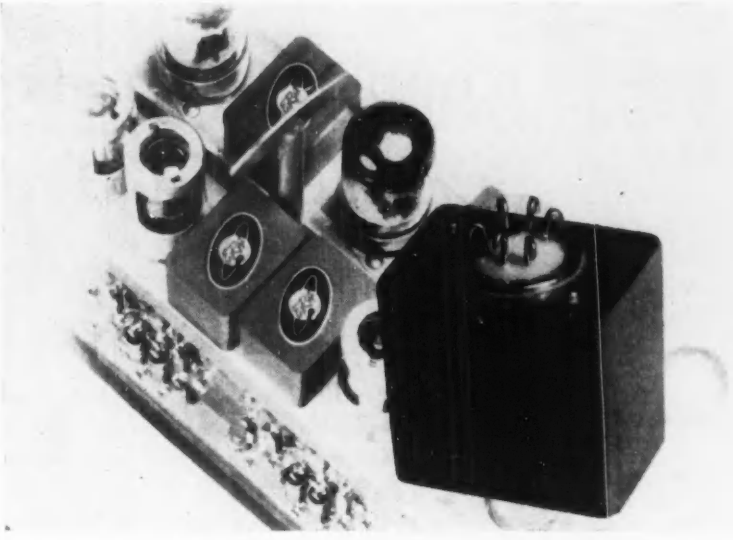
Only KOPPERS *can furnish K-Spun and Porous Chrome!*

Miniature Pulse Transformer for Low Power Use

The ERA type 130A1 multi-purpose, miniature pulse transformer, designed especially for use in low power applications, has three isolated windings to increase its field of application, and a through-panel mounting using the same mounting hole pattern as a conventional nine-pin miniature tube socket. In addition, the compact transformer design permits mounting on a tube strip or chassis in about the same space required for a standard miniature tube. The short rise time minimizes circuit design problems.

Nominal pulse width, 0.1 to 0.5μs; turns ratio, 2:1:1; rise time, 0.05μs (max); max voltage, 300 v; min. interval between pulses, 8 times pulse duration; characteristic impedance, 1,300 Ω.

Applications include triggering and counting circuits, blocking oscillators, d-c isolation, inversion, pulse-shaping, and pulse-transmission circuits.



Engineering Research Associates, Inc., 1902 *W. Minnehaha Ave., St. Paul 4, Minn.*

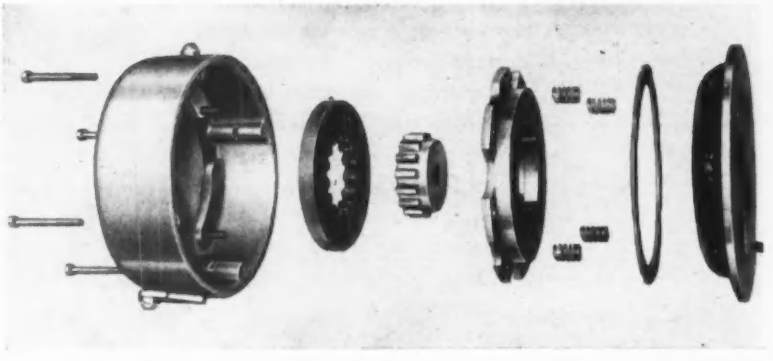
Magnetic Brake Has Shaft Extending Through Brake

A new magnetic brake that eliminates all levers and linkage has been developed with only 6 major operating parts, and features a direct, automatic set and release action between the solenoid and the armature.

In addition to this operational feature, the solenoid is of a one-piece doughnut design that allows the motor's output shaft to extend through the brake. Both ends of the motor shaft are then available for powering two pieces of equipment, if necessary.

The magnetic brakes are also used with fluid coupled motors and gear reducers. The brake is installed on the output shaft of the fluid coupling with the shaft extending through the brake for hook-up to the load.

The lining wear is automatically compensated for by spring tension. The brake torque remains the same and the inspection and hand adjustment procedure is eliminated.



The brake sets by spring action when the current is cut off, and releases magnetically when the current is reapplied. The manual release, and automatic reset permits rotating of the motor's output shaft by hand, if necessary. The brake will automatically reset when the current is applied.

The magnetic brakes are available in 3, 10, and 25 ft-lb continuous duty ratings; and in 15 and 35 ft-lb intermittent duty types. The brakes may be mounted on the standard motors made by this company, or to NEMA "C" face type end bells if company's mounting method is used.

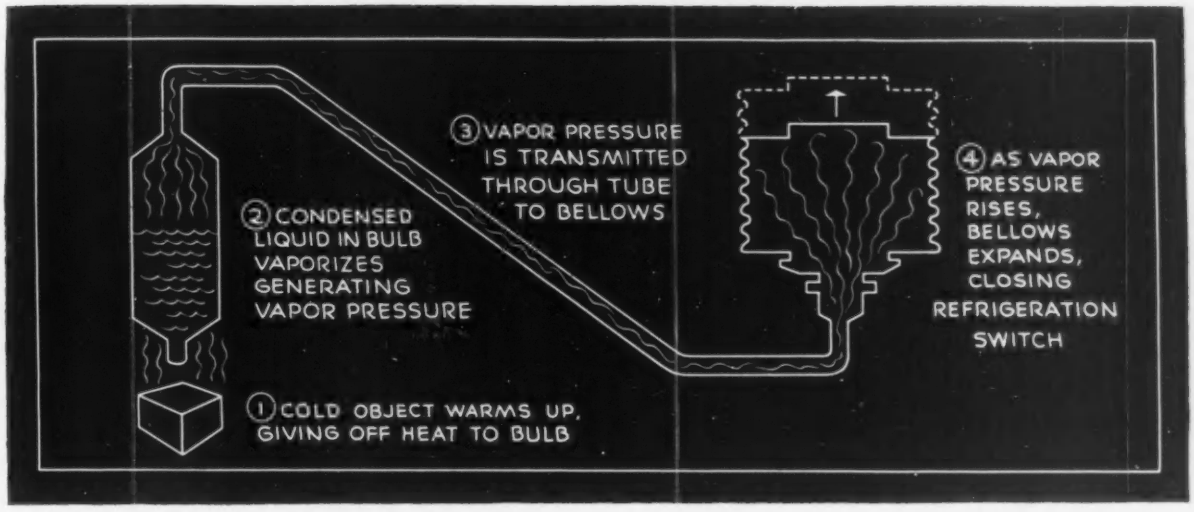
Reuland Electric Co., Alhambra, Calif.

FOUR NEW CAPRISTORS now available, are said to reduce assembly time, save space and costs, and give the full ratings of equivalent standard resistors and capacitors in the manufacture of radio, television, and radar equipment. Capristors, a combination of capacitors and resistors, are equivalent to simple forms of printed circuits. They are larger than printed circuits, but give higher ratings. They are used for diode filters, band pass filters, interstage coupling elements, and other resistor-capacitor circuits. Jeffers Electronics, Inc., Du Bois, Pa.

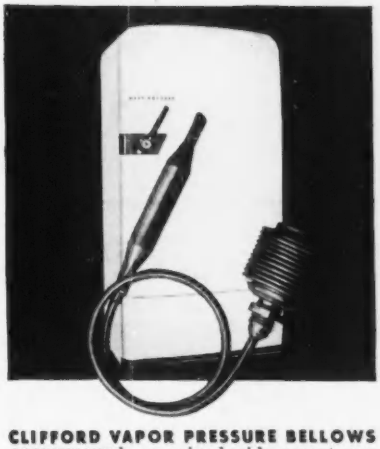
CONTINUED ON PAGE 224

Bellows Digest

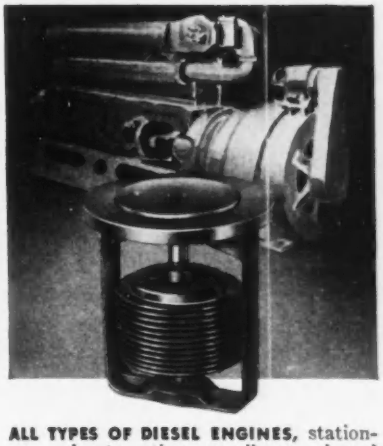
No. 2 **Vapor Pressure Bellows System for Temperature Control commonly used for thermostatic devices requiring close temperature control**


3 VAPOR PRESSURE IS TRANSMITTED THROUGH TUBE TO BELLOWS
2 CONDENSED LIQUID IN BULB VAPORIZES GENERATING VAPOR PRESSURE
4 AS VAPOR PRESSURE RISES, BELLOWS EXPANDS, CLOSING REFRIGERATION SWITCH
1 COLD OBJECT WARMS UP, GIVING OFF HEAT TO BULB

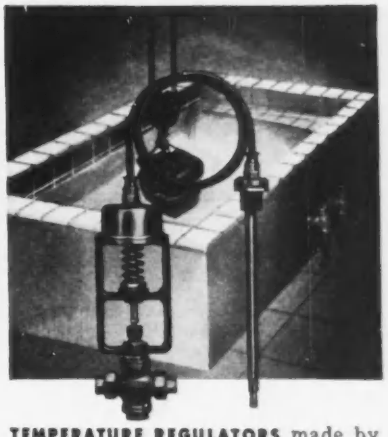
USED FOR THERMOSTATIC CONTROL OR INDICATION, the vapor-actuated bellows assembly above regulates refrigerator temperature. A similar system is available to control heating systems and can be made "fail safe" to prevent overheating if control fails. The system shown meets conditions in which bulb is always *colder* than bellows and capillary. Other systems available where bulb is *warmer* than bellows and capillary. A third system meets *either* condition—bulb colder or warmer than rest of system. Adjustment, generally obtained by spring-loading against pressure developed by bellows, is commonly limited to a lower range than liquid-filled systems, but sometimes allows a narrower differential. Only short bellows travel is required.



CLIFFORD VAPOR PRESSURE BELLOWS ASSEMBLIES have gained wide acceptance among refrigerator manufacturers. Westinghouse and other leading makers depend on these positive-acting components for the close temperature control essential to modern refrigeration.

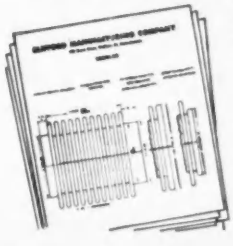


ALL TYPES OF DIESEL ENGINES, stationary and automotive, as well as truck and passenger car gasoline engines, are fitted with thermostats embodying Clifford vapor-actuated bellows assemblies. Simplicity, dependability and easy installation are major advantages.



TEMPERATURE REGULATORS made by Kaye & MacDonald, Inc., are used in water heating or cooling tanks, steam cookers, acid baths, glue heaters, bottle washers, tempering baths, other equipment. Clifford vapor pressure bellows assemblies are the actuating elements.

MAYBE YOU, TOO, CAN BENEFIT from the use of Clifford Hydron Bellows Assemblies. Besides controlling temperature, these flexible, leakproof, metallic bellows are also used to: (1) seal rotary shafts or packless valves against liquid or gas leakage; (2) transmit motion hydraulically to remote points; (3) provide for thermal expansion in many types of applications; (4) provide shock mountings or vibration dampening; (5) permit motion in a vacuum.



FREE! BELLOWS TEMPLATE KIT
Trace 20 most popular bellows sizes . . . fast . . . accurately. Kit, in handy cardboard envelope, includes full directions and details of Clifford bellows. Simplify tedious jobs—send for your Kit today.

Write Clifford Manufacturing Company, 122 Grove Street, Waltham 54, Massachusetts. *Division of Standard-Thomson Corporation.* Sales offices in New York 17, Detroit, Chicago 1, Los Angeles.

38.2.9

General Purpose, Dual-Beam Oscillograph

The compact, type 322 dual beam oscillograph, designed specifically for general purpose laboratory and industrial applications, is essentially two type 304-H oscillographs in a single cabinet. It has the features of the type 304-H, with the additional advantages of a dual beam presentation on either common or individual sweeps, amplitude calibration of either axis of both channels, and centralized controls.

The type 5SP cathode-ray tube used in the type 322 is operated at an over-all accelerating potential of 3,000 v, producing a bright trace capable of good resolution. Stable high-gain a-c and d-c amplifiers are used for both axis. Sinusoidal frequency response of the X and Y axes of both channels is down not more than 10 percent at 100,000 cps, and down not more than 50 percent at 300,000 cps, with a deflection factor of 0.028 peak-to-peak volts per in. on the vertical axis, and 0.28 peak-to-peak volts per in. on the horizontal axis.

Driven and recurrent sweeps are continuously variable from 2 to 30,000 cps. Complementing the d-c response of the vertical axis, sweeps of long duration can be made available by connecting the external capacitance to front-panel binding posts.

Because of the mechanical layout of the type 322, as well as to the use of concentric controls, this new dual beam instrument is no larger than the standard 5 in., single-channel oscillographs. Other features include an illuminated calibrated scale with a dimmer control, and balanced input at maximum sensitivity, in addition to the conventional single-ended input. The manufacturers claim that the type 322 oscillograph is a versatile, general-purpose unit, suitable for use in research laboratories, while being sufficiently compact and sturdy for production applications.

Allen B. DuMont Labs, Inc., Instrument Div., 1500 Main Ave., Clifton, N. J.

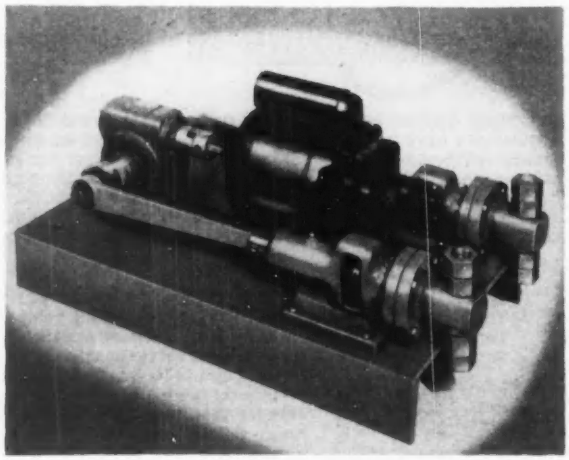
Variable Capacity, Simplex or Duplex, Plunger Pump

The high pressure, variable capacity, proportioning pump shown is part of a new chemical feed packaged unit, which delivers liquids in desired amounts under pressure. The rest of the unit is a reservoir tank of 50 or 100 gal capacity, and a special designed motor-driven agitator to give completely mixed fluids at all times.

The proportioning pump, which is either a simplex or duplex is a reciprocating plunger pump, designed for application where a controlled capacity of fluid is required. The pump uses dual suction and discharge valves. As the efficiencies and the capacities become more uniform when the valves are spring loaded, both discharge valves and the top suction valve have stainless steel springs to give positive action.

The proportioning pump can be designed for various rates of feed at different pressures. Special variable speed drives are available for capacity adjustments while the pump is in operation. Standard motors, and gear reducers with a 24 to 1 ratio are used.

Other particulars: the oversized crosshead, which is solid bronze, 1¾ in. dia and 2 in. long, runs in a machined crosshead guide; needle bearings are used for the connecting rod bearings. The pump is constructed to simplify the changing of packing without breaking the piping connections. For pumping solids in suspension the viscosity must be known, and special construction, such as oversized valves, and water seals, is necessary.



The Bird-Archer Co., 4337 N. American St., Philadelphia 40, Pa.

CONTINUED ON PAGE 226

"In this plant, my good man, we make sure you remember to get a bid from Hoover before you place an order for die castings!"

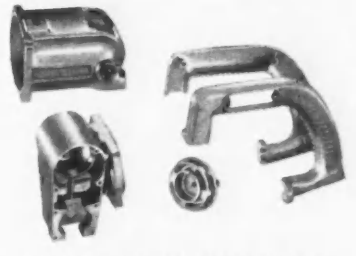
Where quality comes first...Hoover Die Castings

When in the market for die castings, most manufacturers like to have Hoover in on the bidding.

That's partly because Hoover has a reputation for hair-splitting accuracy—partly because Hoover has a way of coming through with tough assignments on time. And while Hoover's bids may not always be the lowest, they do represent a low price for *quality.*

Whether you make a product that can be die cast completely or only in part, Hoover die castings can help you turn it out faster—and probably with big savings in both material and labor.

Like to talk it over? Hoover is set up to work with your product designers and engineers every step of the way, or to take complete charge from drawing to delivery.



20% RETURN ON INVESTMENT

Die cast by Hoover, these precision parts for a well-known make of steel-cutting shears have reduced material costs 41% and direct labor costs 19%. After absorbing die costs, savings are expected to return at least 20% per year on the investment.

May we show you other examples of Hoover die casting? Write for free booklet, or for a Hoover engineer to call.

THE HOOVER COMPANY, Die Castings Division, North Canton, Ohio

HOOVER

Specialists in the field of die castings since 1922

Automatic Bin-Level Control Switches

In addition to a line of normal duty, automatic, bin level control switches, a heavy duty model, and an explosion-proof model are being manufactured to meet special installation conditions. These Tellevel switches are designed so that a rising or falling level of material in bins deflects a pendant float actuating a micro switch that will stop or start feed conveyors or elevators, or light a warning light.

The explosion-proof switch is designed for operation in areas where explosive vapors and dust occur. It is approved by the Underwriter's Laboratory for classifications including: vapors and dust from such materials as ethyl ether, gasoline, alcohol, acetone, coal, grain and flour.

Where materials, such as coal, stone and ore with lump sizes above $\frac{3}{4}$ in. are being discharged to bins, the heavy-duty switch is recommended. This unit is furnished with a steel housing protecting the switch mechanism, with the standard plastic float ball being replaced with a steel cone. A rubber cup at the base of the housing forms a dust and moisture proof seal to protect the switch mechanism.

Stephens-Adamson Mfg. Co., Aurora, Ill.

Direct Reading, Indicating Pyrometer Controller

The development of a compact, direct reading, indicating pyrometer controller with a built-in unit to give straight line control, makes it possible to have a type of proportioning control for processing equipment such as ovens, furnaces, kilns, vats, and plastic molders without using auxiliary devices.

The instrument operates with the electronic link, also made by this company and used in its line of controllers, but adds a new line-otrol feature that automatically reduces to a minimum the on and off variation of the control instrument above and below the preset control point. This is said to give a hair-line control of the process variable.

The on-off type controller uses the same measuring system with the alnico V magnet and control assembly used in the model 292, but it is able to compensate for the transfer lags found in most process control systems.

The instrument is $7\frac{5}{8}$ in. wide by $8\frac{1}{8}$ in. high by 7 25/32 in. deep, making it a space saver for flush or surface mounting on original heating equipment, or on instrument panels. A wide range of standard scales coming in various thermocouple calibrations are available.

Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.

PARALLEL LINES, either horizontal, vertical, or diagonal can be spaced from a thousandth part of an inch up to an inch or more on any size sheet. A controlled index wheel on the paraliner board is set up against a measuring scale at the desired space. The ruling edge is moved forward step by step while the lines already set by the index, are drawn. It is useful in drafting and engineering layouts because of the built-in micrometer precision instrument. Michael Lith Co., 145 W. 45 St., New York 36, N. Y.

A COMPACT, AIR OPERATED COLLET holding fixture permits multiple installation on production indexing tables or where previously rapid positioning of small parts has been impossible. This model uses standard shop collets 1A and 3C styles up to $\frac{1}{2}$ in. capacity. Overall size is $2\frac{1}{16}$ in. high by $3\frac{9}{16}$ in. in diameter. Special design permits handling of long pieces through the fixture. Modernair Corp., 400 Preda St., San Leandro, Calif.

—CONTINUED ON PAGE 228

Steel veins for iron horses

Steel veins for iron horses—strong, durable veins easily forged and fabricated to exact requirements—this is but one of the many applications for OSTUCO Tubing in products of modern design, products that strengthen America and the free world.

OSTUCO Tubing presents endless opportunities for improving design in almost every field. In addition to infinite adaptability, OSTUCO Tubing offers such advantages as maximum strength with minimum weight, good surface conditions for finishing, excellent machinability, and low cost. We cannot always promise early delivery estimates on new civilian orders, because of military demands, but it will pay you to consult our experienced engineers about OSTUCO Tubing when redesigning your products to meet future competition.

From Your Blueprint . . . to Your Product
OSTUCO TUBING
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Upsetting • Expanding • Reducing • Beading
End closing • Spinning • Drilling • Slotting
Notching • Flattening • Shaping • Trimming
Threading • Angle Cutting • And Many Others

THE OHIO SEAMLESS TUBE COMPANY
Manufacturers and Fabricators of Seamless and Electric Welded Steel Tubing
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4 STAR TIMER

★ No false contacts
★ No chatter
★ Quiet in operation
★ Eliminates double contacting or breaking of circuit

HYDROGEN PACKED

Durakool
STEEL MERCURY TIMERS

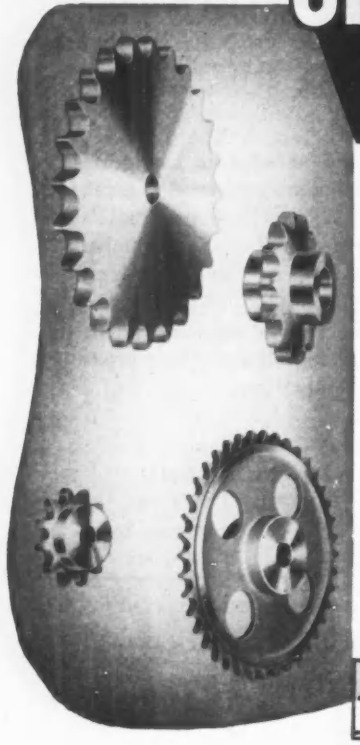
The steel-clad "fixed time" Durakool timer-relay operates in "sealed in" hydrogen under pressure, with mercury to mercury contacts. Timing is tamperproof. Non-breakable and built for millions of contacts. Fixed time delays available from 1/6 to 20 seconds, either normally open or normally closed action.

See Telephone Directory for Local Distributor or write Durakool, Inc. Elkhart, Indiana

Send for Bulletin 800

Sewall SPROCKETS

Carried in Stock or made to order



SEND FOR THE SEWALL CATALOG listing all types of stock sprockets. Sewall roller chain sprockets are available for conveying and power transmission uses. We cut sprockets to order for any type of roller or silent chain. Large and small sizes . . . any material or quantity.

Also Manufacturers of
SEWALL GEARS
—Custom Made For Every Need

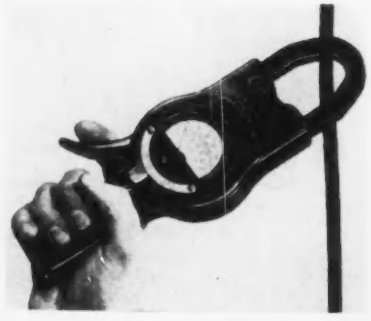
E. B. SEWALL MANUFACTURING CO.
695 Glendale St., St. Paul 4, Minn. • NEstor 6381

Clamp Type Instrument Measures Volts and Amperes

The new type AC-1 volt-ammeter is a clamp-type, hand sized measuring instrument that may be used for two separate jobs: measuring volts and amperes.

Readings are made without breaking circuit or insulation. To read amperes, the trigger is pressed, opening the pair of insulated jaws so that they can encircle the power cable or bus bar. The jaws will accommodate cables up to $1\frac{1}{2}$ in. in dia, and bus bars up to 2 in. x $\frac{1}{2}$ inch. Four amperage ranges are available: 0-12, 0-60, 0-120, 0-600 a-c amperes.

For measuring voltage, the leads



are plugged into the handle of the instrument. Two voltage ranges are available, 0-150, and 0-600 a-c volts.

Small enough to be carried in a pocket, (and weighing less than two pounds), the instrument may be held and operated with one hand. Overall dimensions are 11 in. x $3\frac{1}{2}$ in. x $1\frac{7}{8}$ inches.

The trigger and housing of the instrument are constructed of a molded phenolic material. Accuracy is plus or minus 3 percent of full scale deflection. Complete unit includes voltage leads and carrying case.

Columbia Electric Mfg. Co., 4553 Hamilton Ave., Cleveland 14, Ohio

Precision Control Pressure Regulator

Designed to give precision control of air pressure in the range of 0-2 cfm, this regulator, according to the manufacturer, is the first regulator developed which will give exact control of pressure in the range from 0 to 30 psi.

It is especially suited for use with air-controlled instruments, but may be used in any process requiring air, nitrogen, or other inert gases whose pressures must be precisely controlled. The unit operates on primary line

What's U. S. Rubber doing for designers?

This pipe, used for handling corrosive solutions, is one of the many products made of Enrup, U. S. Rubber's new compound. It is readily adaptable to processing by a wide variety of methods. Enrup has high chemical resistance, temperature resistance, and exceptional toughness.

The graph below shows the range of hardness in which Enrup shows up to best advantage. New design potentialities are constantly coming to light, since Enrup fills the gap left by the limitations of other materials.

DESIGNERS and other users of plastics and rubber compounds now have a great new compound at their disposal. They need no longer be handicapped by the lack of a high-strength material, of a hardness of 85 Shore Durometer A with a modulus of 5,000 up to 80 Shore Durometer D with a modulus of 250,000.

This U. S. Rubber development is Enrup, a thermosetting plastic. Enrup has excellent impact strength, good stability and structural strength. It has a steadily mounting list of uses and applications.

Enrup may be just what you have been looking for to solve your design problem. For information write to address below.

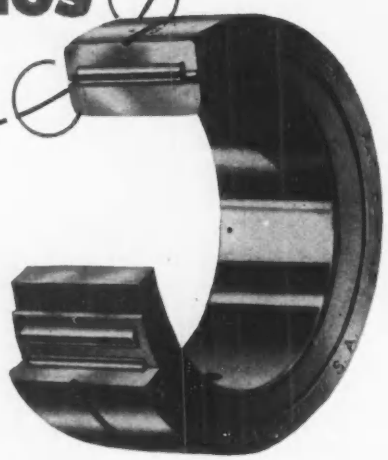
PRODUCT OF
U.S.RUBBER
SERVING THROUGH SCIENCE

UNITED STATES RUBBER COMPANY

MECHANICAL GOODS DIVISION • ROCKEFELLER CENTER, NEW YORK 20, N. Y.

RBC's
New Concept!
New Product!

PITCHLIGN
TRADE MARK
ROLLER
BEARINGS



An entirely new principle of bearing construction! RBC's PITCHLIGN cage keeps the rollers in perfect alignment by contact at the roller *pitch circle*. Rollers cannot cock or skew!

Internal stresses are reduced to an absolute minimum in PITCHLIGN bearings because the cage acts *only* in the direction of rotation at a point coincident with the roller orbit. Again, accumulated tolerances or wear of load carrying surfaces have no effect on the overall efficiency of the cage, since it is supported by the two integral flanges of the heavy outer race.

PITCHLIGN is not merely an improvement on a standard type bearing—it represents an entirely *new concept*, developed in an entirely new product . . . dimensionally interchangeable with precision needle bearings.

PITCHLIGN's performance potential can save you time and money. Get The Facts!

Write Today *Ask for Bulletin SF-166*

RBC
ROLLER BEARING COMPANY OF AMERICA • TRENTON, N. J.

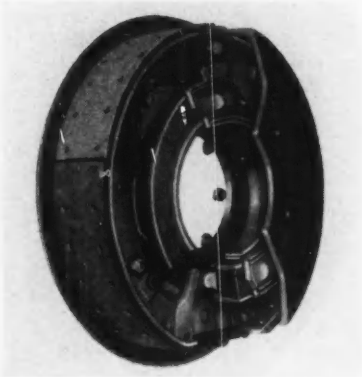
pressures up to 400 psi, with delivery pressures ranging from 0 to 30 psi. The regulator has a built-in relieving feature which prevents a build-up of excessive pressures.

For longer life, three parts are made of nylon: the relief valve seat; the regulator valve, a nylon ball; and a nylon reinforced synthetic rubber diaphragm.

C. A. Norgren Co., 3428 S. Elati St., Englewood, Colorado

Large Electric Brake for Industrial Machinery

A large size electric brake, suitable for heavy use is expected to be useful in such industries as: construction; oil fields; steel mills; lumber factories; and larger type machine tools. The new brake will make it possible to convert to electrical stop and start equipment, where formerly only mechanical and hydraulic systems were used. The brake measures 15 in. in diameter, 5 in. in width, and is said to be the most powerful electric brake developed by the company for use on industrial machinery.

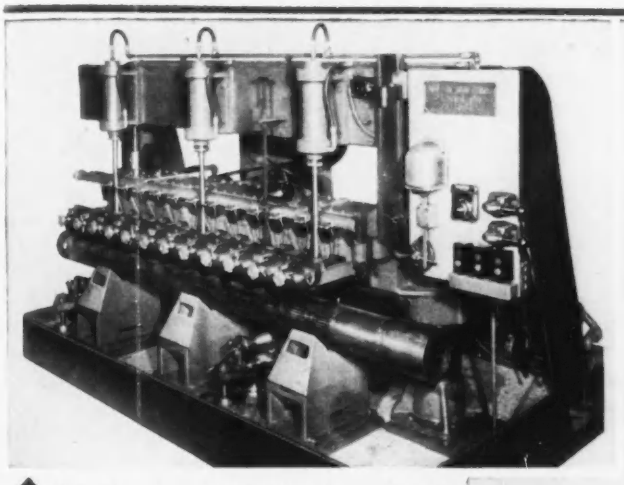


Warner Electric Brake & Clutch Co., Beloit, Wisconsin

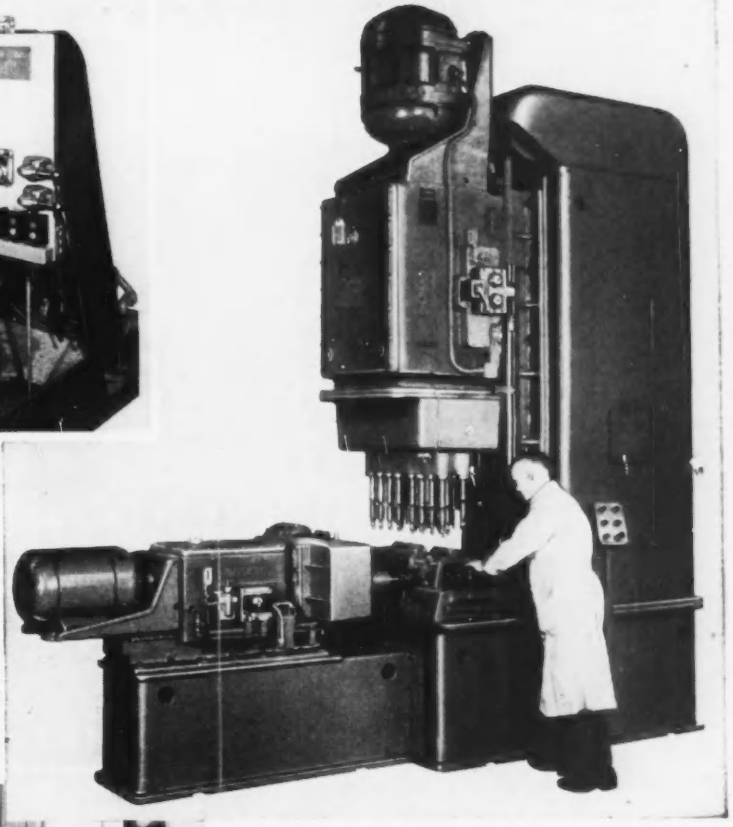
Surface Pyrometer for Precision Measurement

Known as the Pyro surface pyrometer, a new instrument is available with a selection of 14 different types of thermocouples and extension arms for all surface and sub-surface measuring problems. It can be equipped with a new quick-change connector which permits the thermocouples to be snapped and locked onto the extension arms. These thermocouples are interchangeable without adjustment or recalibration. The lock-swivel permits locking the thermocouples at any

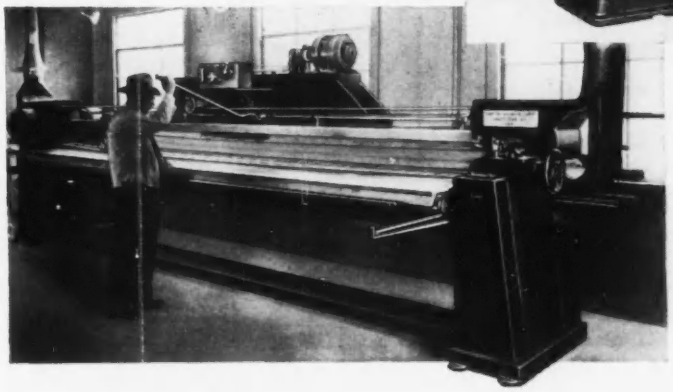
MORE COST-CUTTING APPLICATIONS OF VICKERS HYDRAULICS



Oil well casing slotting that formerly cost $1.25 per foot is now done at $0.90 per foot on the new machine designed and built by Allen Machine & Tool Co., Compton, California. Vickers hydraulic equipment raises and lowers the feed rail, controls feed rate and rapid traverse of cutters.



Hydraulic unit converted old belt sander to modern automatic stroke sander and reduced time for sanding pew backs from 15 minutes to 1½ minutes. Also improved quality. Built by Curtis Machine Corporation, Jamestown, N. Y. Vickers Hydraulics used exclusively.



This four-way, 38 spindle special purpose machine by Modern Tool Works, Ltd., Toronto, Ontario, does the drilling, spot facing and chamfering operations on an automobile engine head at the rate of one per minute. Vickers Hydraulic helps give it speed, control and precision.

Every day more and more machines are increasing production and cutting costs with the help of Vickers Hydraulics. See for yourself what Vickers Hydraulics can do for you . . . write for Catalog 5000 or call in a factory trained Vickers application engineer.

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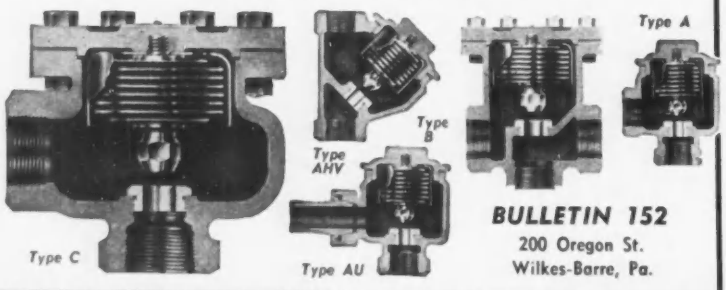
ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

4763

Nicholson Traps Help

CUT STEAM COST $500,000 A YEAR

At one of the nation's large processing plants a campaign to promote economical steam use by improving heat transfer efficiency has resulted in a yearly saving of $500,000. Credit for a fair portion of this is given to improved steam trapping which resulted from the installation of Nicholson thermostatic traps. To see why an increasing number of leading plants are standardizing on Nicholsons for positive drainage and faster heat transfer, send for Bulletin 152.

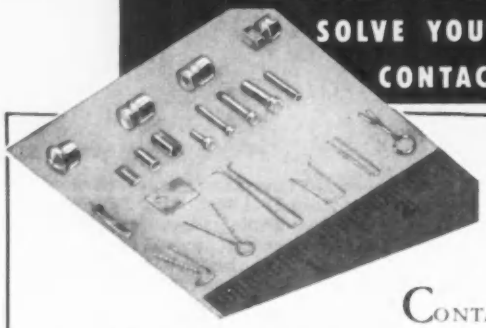


BULLETIN 152
200 Oregon St.
Wilkes-Barre, Pa.

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

LET NEY EXPERIENCE AND EXPANDED PRODUCTION FACILITIES SOLVE YOUR CONTACT PROBLEMS



CONTACTS, brushes, wipers, slip rings, commutator segments and similar components for electrical instruments and apparatus represent a field in which Ney Research has a long list of important accomplishments. Ney precious metal alloys specially developed for these applications are widely and very successfully used. And now enlarged manufacturing facilities have been added to meet the steadily increasing demand. If you have applications in any of these categories, write at once for the Ney Technical Data Book No. R-12. Or call our Engineering Department outlining your needs.

THE J. M. NEY COMPANY • 109 Elm Street
HARTFORD 1, CONNECTICUT

angle while the measurement is being made.

The pyrometer is shock, dust, and moisture-resistant, and made to withstand rough usage. It is available in five different temperature ranges.

Pyrometer Instrument Co., Inc., Bergenfield, N. J.

Small, Hand Operated, Hydraulic Cutter

Weighing only 12 lb, and measuring 21 in. in length, this model 200-A hydraulic cutter is able to exert a pressure of 8,500 lb psi, and cut $\frac{1}{2}$ in. reinforcing rod. The units were designed to replace larger bolt cutters, and reduce operator fatigue.

Another feature of the cutter is a dual ratio pump which will combine fast traverse with high power to minimize the cutting time. The reduced operator effort will eliminate some of the twist motion that causes cutter blade breakage. Blades are of alloy tool steel and can be resharpened.

The Manco Mfg. Co., Bradley, Ill.

Writing Slide Rule Device

A new writing slide rule has among its ten functions: a telescoping measuring scale; a reading magnifier; a depth gage in inches and centimeters; a detachable straight-edge; concealed eraser and spare pencil leads; and a plain and enlarging indicator for slide rule's A, B, C, D, L, S, T, CM, and IN scales.

The instrument is made of high quality plastic materials, and of gold or nickel double plated brass and steel parts. Scale graduations are debossed against wear by a new marking process.

Writing in a choice of two colors, the instrument is $6\frac{1}{2}$ in. long, and weighs only 0.8 ounces.

Device Development Co., 226 W. Fourth St., New York 14, N. Y.

Precision On-Off D-c Timer

Providing timing cycles from 3 seconds to several minutes, a precision on-off d-c timer may be used for: limiting the operating cycles on jet engine igniters; to sequence or limit the operation of solenoid valves, or other units where safety of equipment requires delays in frequency or duration of operation.

Accuracy of the timing mechanism

Silicone* PUTS HOT JETS IN COLD SKIES!

*

For High and Low Temperature Applications . . . Specify Stalwart Silicone Rubber Parts

Only Silicone parts can combat these two enemies — extreme cold and intense heat. Stalwart-engineered Silicone rubber parts retain their physical, chemical and dielectric properties at temperatures ranging from **-110 to +500°F.**

Stalwart Silicone parts have excellent resistance to many chemicals, weathering, oxidation, moisture, ozone and other factors that destroy organic rubbers.

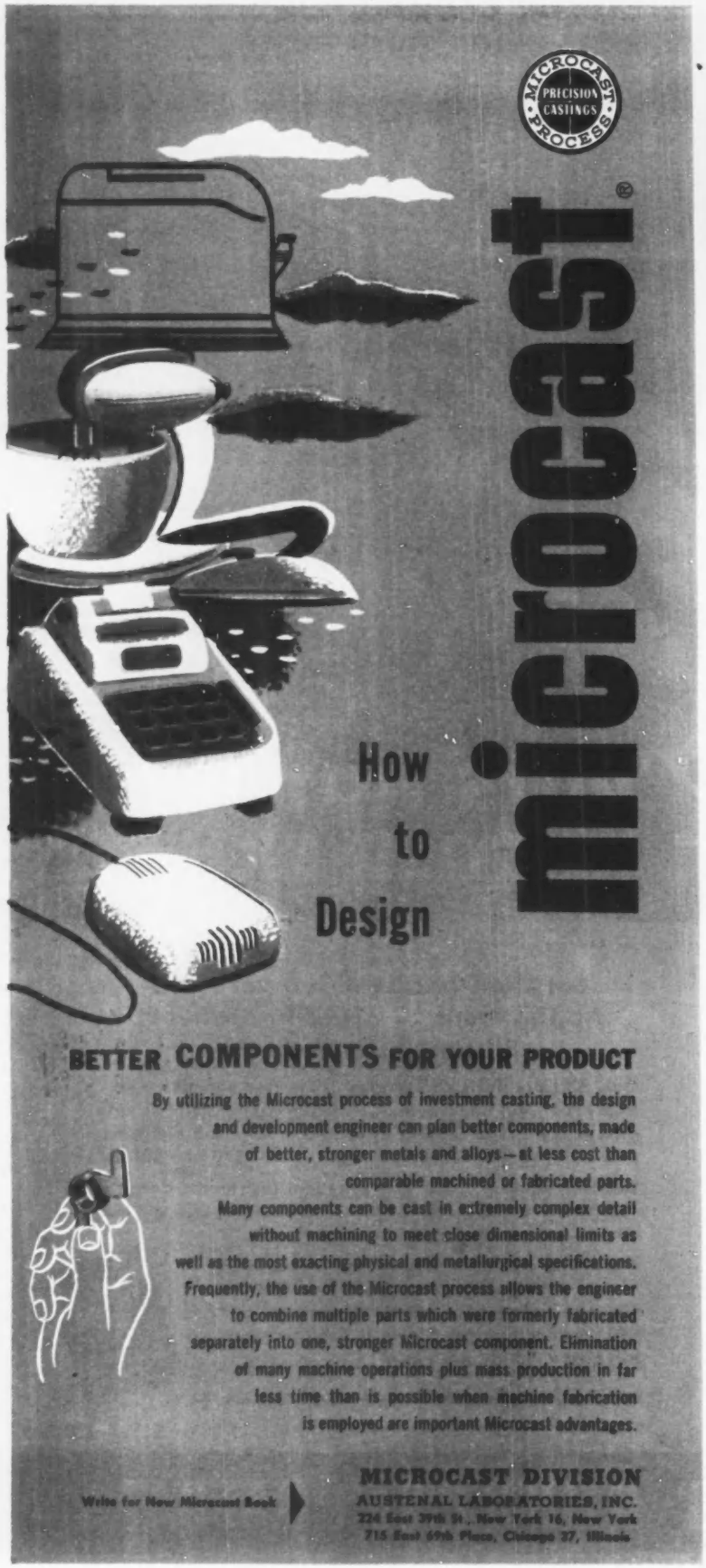
Stalwart is equipped to produce a wide range of precision parts from Silicone to meet the needs of aviation, automotive, electrical and other industries. **Let Stalwart Silicone parts solve your rubber problems!**

Write today for Catalog 51SR-1 for complete information.

613-SR

STALWART RUBBER COMPANY

200 NORTHFIELD ROAD • BEDFORD, OHIO


MICROCAST PRECISION CASTINGS PROCESS
How to Design microcast®
BETTER COMPONENTS FOR YOUR PRODUCT
By utilizing the Microcast process of investment casting, the design and development engineer can plan better components, made of better, stronger metals and alloys — at less cost than comparable machined or fabricated parts.
Many components can be cast in extremely complex detail without machining to meet close dimensional limits as well as the most exacting physical and metallurgical specifications. Frequently, the use of the Microcast process allows the engineer to combine multiple parts which were formerly fabricated separately into one, stronger Microcast component. Elimination of many machine operations plus mass production in far less time than is possible when machine fabrication is employed are important Microcast advantages.
Write for New Microcast Book
MICROCAST DIVISION
AUSTENAL LABORATORIES, INC.
224 East 39th St., New York 16, New York
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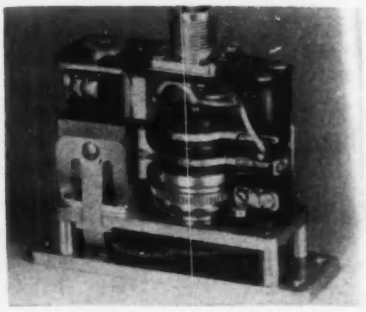


is made possible by a constant speed clutch which eliminates the use of clockworks or other cycling devices. The timer automatically resets itself instantaneously upon interruption of current to the holding coil. A conventional shunt wound motor is used to drive the mechanism.

Adjustment of timing cycles from 3 to 90 sec can be made in the basic unit. Modification of the gear train will give cycling up to several minutes.

Bendix Aviation Corp., Pacific Div.,
11600 Sherman Way,
North Hollywood, Calif.

Illuminator for X-Ray Film

A full 14 by 17 in. viewing surface on a new high intensity illuminator makes X-ray film inspection of industrial parts quick and accurate.

The unit is said to have an even light intensity 20 times greater than conventional viewers, plus a 3 in. spot of four times the overall intensity for a critical examination of small areas. This is possible for films having a density range greater than 4.5 density.

Other accessories are: separate masks for films of smaller than 14 x 17 in. size; cool front operation does not harm film; foot switch control; and stepless voltage brightness control.

Keleket X-Ray Corp.,
225 W. Fourth St., Covington, Kentucky

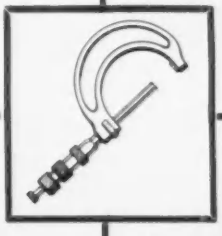
Long Life Power Supply Unit

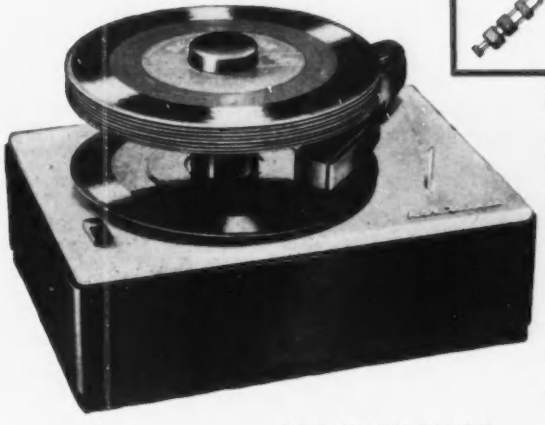
Having a load rating of 0-300 ma., the new model One, 300 v d-c regulated power supply is an electronic laboratory instrument designed for long life and reliability. Output voltage is manually adjustable over a plus and minus 10 percent range by means of a precision bridge. Filtering and a high gain ultrastable regulator give an impedance level below $\frac{1}{10}$ ohm, with a combined ripple and jitter less than $\frac{1}{2}$ millivolt. To withstand impulse

When performance depends on dimensional STABILITY

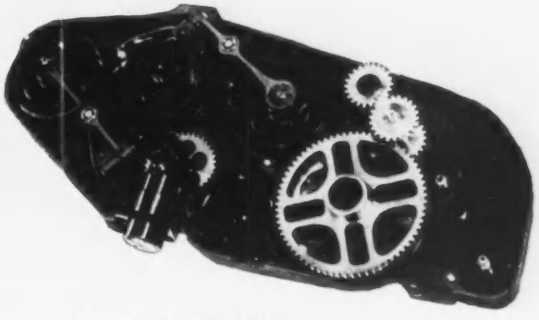
AIRCRAFT LANDING LIGHT PARTS
Grimes Manufacturing Co.

THREE-DIMENSIONAL CAMERA
Stereoscopic, Inc.





PORTABLE RECORD PLAYER
RCA Victor, Inc.



AERIAL CAMERA MAGAZINE
Ryan Industries, Inc.

...see how DUREZ phenolics measure up

● When products or parts must hold their size and shape, even under adverse service conditions, Durez phenolics are often the best answer. Best from the cost angle, too.

In the case of the aircraft landing light, plastic components of the lowering and raising mechanism function unfailingly in all sorts of weather.

The slick black body of the 3-dimensional camera conforms to the close tolerances that hobbyists expect, yet use of Durez cut many dollars from the selling price.

In the record player turntable, vertical wobble or lack of concentricity are successfully avoided. In the aerial camera magazine, the Durez and metal used were tested to function successfully together in a temperature range of −65°F. to +160°F.

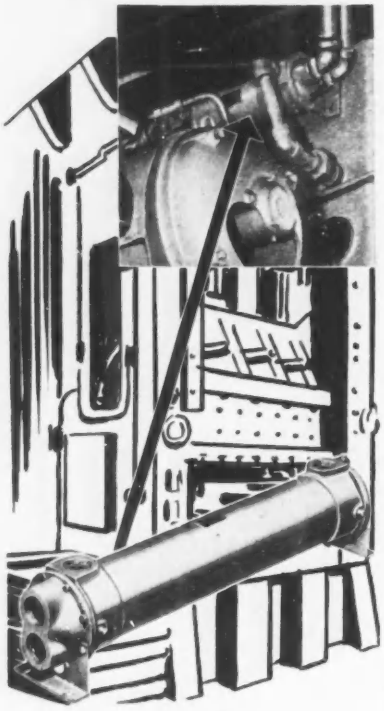
Dimensional stability is but one in a long list of properties offered by the hundreds of phenolic materials we have developed. Resistance to heat, to impact, moisture, and chemicals, electrical strength, light weight, and lustrous natural surface are others. Most important these days, availability and finished cost make phenolics a wise choice.

Your custom molder — and Durez technicians — are ready to work with you.

Our monthly "Durez Plastics News" will keep you informed on industry's uses of Durez. Write, on office letterhead, to Durez Plastics & Chemicals, Inc., 2006 Walck Road, North Tonawanda, N. Y.

PHENOLIC PLASTICS THAT FIT THE JOB

CONTROL
HYDRAULIC FLUID TEMPERATURES!



THERE ARE 132 STOCK YOUNG HEAT EXCHANGERS TO ASSURE OPTIMUM COOLING

Young standardized shell and tube heat exchangers are quality-built to control fluid temperatures and protect costly hydraulic equipment. For example, tubes are braised to tube sheets which, in turn, are braised to the shell to eliminate leakage between hydraulic fluid and coolant. Tube and baffle spacing are engineered to provide maximum heat transfer with minimum pressure drop. Immediate shipments can be made from stock. Catalog sent upon request.

YOUNG RADIATOR CO.

Heat Transfer Products for Automotive and Industrial Applications. Heating, Cooling, and Air Conditioning Products for Home and Industry.

Dept. 282-F • RACINE, WISCONSIN

Factories at Racine, Wisconsin and Mattoon, Illinois

loads, the output terminals are directly shunted by a 15 mfd oil condenser. All transformers and inductors are hermetically sealed, and have grain-oriented cores. This model is for either bench or rack use.

Eastgap Co., 285 Columbus Ave., Boston 16, Mass.

Small Size, Wide Range Choke Coils

Featuring a small size and wide range of inductance, a new series of small radio frequency choke coils is made with insulated copper wire, with the coils having a molded jacket made

of a mineral filled thermosetting compound that permits use under severe service conditions.

The coils made in types 101, 102, and 104, have no shorted end turns, and the windings are soldered to the leads.

Jeffers Electronics Inc., Dubois, Pa.

Hermetically Sealed Instruments

Manufactured with ruggedized and hermetically sealed mountings, this electrical indicating instrument offers an accurate and sensitive means for

THOMAS
Flexible ALL METAL COUPLINGS
FOR POWER TRANSMISSION REQUIRE NO MAINTENANCE

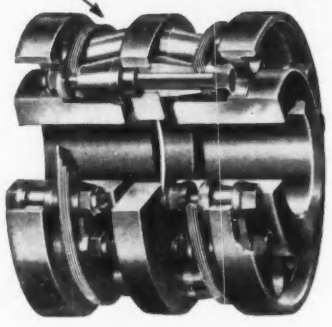
Patented Flexible Disc Rings of special steel transmit the power and provide for misalignment and end float.

Thomas Couplings have a wide range of speeds, horsepower and shaft sizes:
½ to 40,000 HP
1 to 30,000 RPM

Specialists on Couplings for more than 30 years

BACKLASH FRICTION WEAR and CROSS-PULL are eliminated
Lubrication is not required!

PATENTED FLEXIBLE DISCS



THE THOMAS PRINCIPLE GUARANTEES PERFECT BALANCE UNDER ALL CONDITIONS OF MISALIGNMENT.

NO MAINTENANCE PROBLEMS.

ALL PARTS ARE SOLIDLY BOLTED TOGETHER.

Write for the latest reprint of our Engineering Catalog.

THOMAS FLEXIBLE COUPLING CO.
WARREN, PENNSYLVANIA

GITS Unit* SEAL
Now STANDARDIZED

For . . .

Gear Reduction Units
Aircraft Reciprocating Engines
Automotive Accessories
Jet Propulsion Units
Washing Machines
Standard & Special Machine Tools
Electrical Power Equipment
Business Machines

If *you* have a shaft sealing problem, Gits experience in these and many other specific applications can prove of great and immediate value to you.

Write today for FREE illustrated Brochure, or send us your seal problem.

*Cartridge Seal . . . pressure balanced . . . requiring only 25% more space than lip-type seals.

GITS BROS. MFG. CO.

1838 S. Kilbourn Ave. • Chicago 23, Ill.

Gits Lubricating Devices,
The Standard For Industry For Over 40 Years

ENGINEERS NOTEBOOK

HEAT AND VENT SYSTEMS

(PHOTO COURTESY NORTH AMERICAN AVIATION)

QUICK COUPLING

handles pressure and temperature in de-icer system

Marman V-Band Couplings with patented Quick Coupler latches connect the shut-off valve, pressure limiting valve, and air supply line from engine compressor to anti-icing line in the F-86. In this application they are called upon to withstand pressures of 125 p.s.i. and temperatures of 600°F. This is one of thousands of applications where these standard couplings furnish a light weight, positive seal for tubing and ducting under difficult conditions of temperature, pressure, vibration and stress. The Quick Coupler latch insures maximum speed in assembly and disassembly. Marman's ten years of specialization in the design and production of clamps, straps and couplings of all kinds assure consistent and dependable quality.

FOR INFORMATION, WRITE DEPT. E-6

MARMAN PRODUCTS CO., Inc.
11214 EXPOSITION BLVD.
WEST LOS ANGELES 64, CALIF.

SAVE TIME, WEIGHT, MONEY WITH MARMAN

electrical measurement under conditions of shock, vibration, tumbling, and extremes of weather conditions.

It is completely interchangeable with all existing ruggedized types in a-c or d-c ranges, and the $2\frac{1}{2}$ and $3\frac{1}{2}$ in. sizes meet the dimensional requirements of JAN-1-6. These meters are now being manufactured in standard $1\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$, and $4\frac{1}{2}$ in. sizes.

Phaostron Co., 151 Pasadena Ave., South Pasadena, Calif.

Drafting Machine Is Complete Drawing Unit

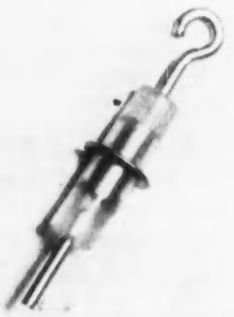
A small size, precision drafting machine for drawings up to 24 x 36 in. is a complete drawing unit in itself, replacing the tee square, triangle, and protractor. Two 8 in. scales are fastened at right angles to the operating head. By pressing the button on top of the plastic knob, the head is released, permitting rotation of the scales with either automatic indexing, every 15 deg, or clamping at any right angle. All movements are under the control of the left hand.

The arms are made of duraluminum with tru-bored brass bushings at each hinge. The mounting bracket is cast and includes a hinge to allow thumbscrew adjustment to level the machine to the board. Hardened pins make the joints free from play.

Evenline Products, P.O. Box 47, East Side Station, Providence 6, R. I.

Hermetic Sealing for Electrical Components

Designed to meet hermetic sealing requirements of MIL-T-27, this solder seal type terminal has a molded polytrifluoromonochloroethylene resin insulating the solder seal from the center terminal rod. The molded body, fabricated from Kel-F, is chemically inert to organic solvents, acids, alkalies, oils,



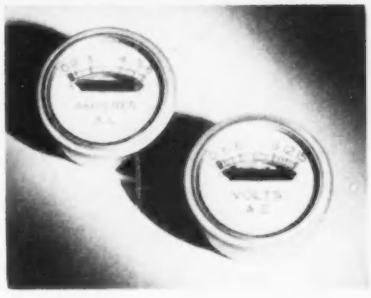
and fumes, is unaffected by high humidity, has zero water absorption, and high resistance to thermal shock, —70 to 190 C. Length is 1 5/16 in.; dielectric strength is 5,000 v rms, 60 cps.

International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.

Small-Sized Indicating Meter

A newly designed, small-sized indicating meter, which is about 40 percent smaller than other models, fits a 1 5/8 in. mounting hole where formerly a 2 1/32 in. opening was required. A back panel clearance of one inch from the flange is needed.

The meters are available in ranges of 1 to 50 v; 1 to 30 amp; 10 to 1,000



milliamperes. While smaller in size, the meters still have good readability and accuracy. They are designed to give a reading accuracy of 5 percent at any given point on the scale with a 10 percent overall accuracy, and are available for either a-c or d-c service.

9212 Detroit Ave., Cleveland, Ohio
***Sterling** Mfg. Co.,*

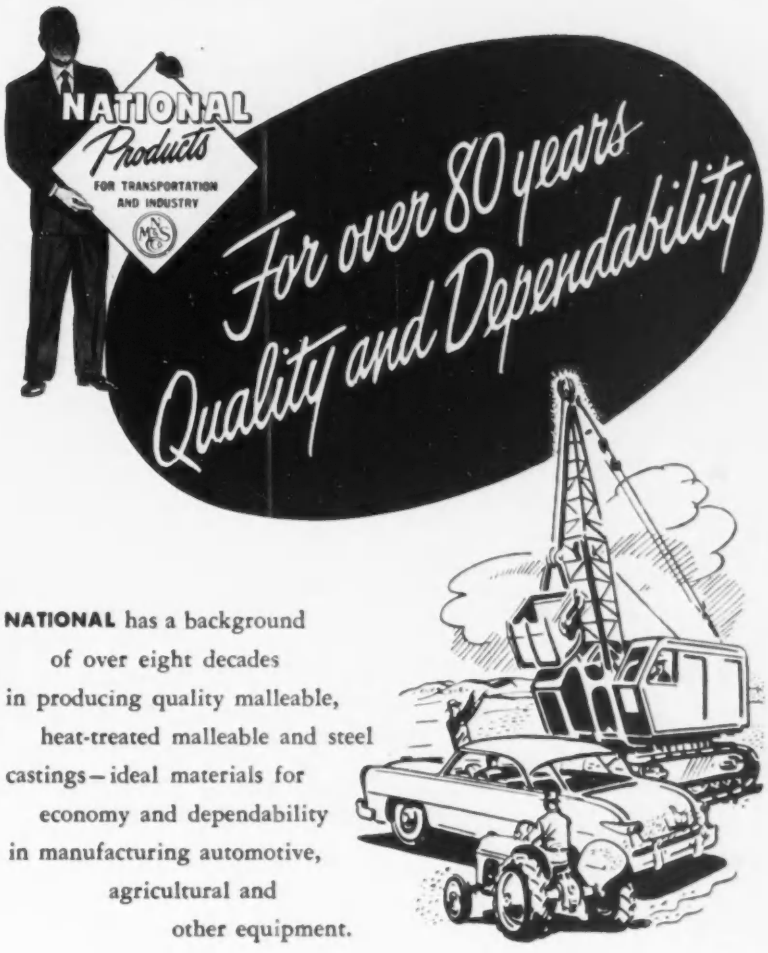
Polyethylene Welded Pipe Fittings

Flanged pipe fittings of Polyethylene are now being made in tees, crosses, 45 and 90 deg elbows, up to 6 in. nominal pipe size. These parts are of welded construction, and are resistant to most corrosive chemicals.

In addition to their use in chemical pipe lines, sewage, and waste installations, they are used in transmission lines for foods, and in drinking water and irrigation systems.

The welded and flanged pipe fittings are made to the standard dimensions of the American standard class 125 cast iron flanged fittings, and can be incorporated into existing pipe lines.

American Agile Corp., P.O. Box 168, Bedford, Ohio



NATIONAL has a background of over eight decades in producing quality malleable, heat-treated malleable and steel castings—ideal materials for economy and dependability in manufacturing automotive, agricultural and other equipment.

NATIONAL'S unparalleled experience—coupled with a continuing metallurgical research program, rigorous quality control standards, and completely mechanized foundries in strategically located cities—is at your disposal.

Sales offices and engineering facilities are located at all five plants listed below.

A 16mm technicolor film. Narrated by Edwin C. Hill, this 27-minute film tells how malleable iron is made . . . tested . . . used . . . how its production economy, ductility, machinability, toughness will give you a better finished product. Available for group showings. A-5017

PLANTS LOCATED IN
Sharon, Pa., Cleveland 6, Ohio, Indianapolis 6, Ind., Melrose Park, Ill., and Chicago 50, Ill.

NATIONAL Products FOR TRANSPORTATION AND INDUSTRY

NATIONAL MALLEABLE and STEEL CASTINGS COMPANY
CLEVELAND 6, OHIO

Countless small parts usually made by conventional turning processes — by stamping, drawing, casting or molding — can be made *better . . . stronger . . . cheaper* by *cold-heading* and roll threading.

Machining of Cold-Headed Parts is hardly ever necessary because shank and head dimensions can be held to very close tolerances. Rolled threads are produced to American Standard dimensions.

Here are just a few of the many parts formed or roll threaded . . .

Screws	Plastic Inserts	Stems
Bolts	Thumb Screws	Arms
Studs	Wing Nuts	Plugs
Rivets	Small Gears	Prongs
Rods	Tongue—Clevis	Points
Links	Segments	Hooks

Single or multiple secondary operations can be performed on cold-headed parts to produce special characteristics required to fit the part for its particular application. These secondary operations include drilling, tapping, milling, shaving, flattening, notching, flanging, trimming, serrating, bending, off-setting, slotting, fluting, swaging, knurling, pointing, heat treating, plating and finishing.

ARE YOU MISSING THIS SAVING?

Write or call in a Pheoll engineer. Explain your production problems. He will tell you where you can save money, speed production, improve your product appearance.

Pheoll MANUFACTURING COMPANY

SCREWS • BOLTS • NUTS

MEETINGS

June 2-13

CANADIAN INTERNATIONAL TRADE FAIR—Toronto, Canada.

June 4-14

MECHANICAL HANDLING EXHIBITION AND CONVENTION — Olympia, London, England.

June 15-19

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Semi-Annual Meeting, Sheraton-Gibson Hotel, Cincinnati, Ohio.

June 16-18

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS—Semi-Annual Meeting, Essex and Sussex Hotel, Spring Lake, N. J.

June 16-20

INDUSTRIAL FINISHING EXPOSITION —Sponsored by American Electroplaters Society, International Amphitheatre, Chicago, Ill.

June 16-26

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION — Ball and Roller Bearings Project, Columbia University, New York, N. Y.

June 17-19

INTERNATIONAL TRADE SHOW OF AIRCRAFT PARTS AND EQUIPMENT—Hotel Park Sheraton, New York, N. Y.

June 19-21

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Applied Mechanics Division, Symposium on Shock and Vibration Instrumentation, Pennsylvania State College, Penna.

June 23-27

AMERICAN SOCIETY FOR TESTING MATERIALS — Fiftieth Anniversary Meeting, Hotels Statler and New Yorker, New York, N. Y.

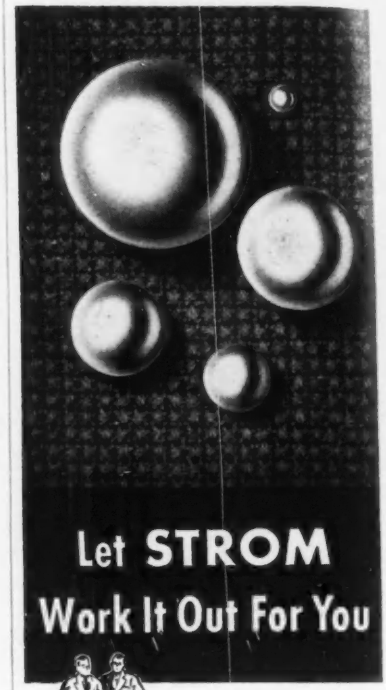
June 24-27

AMERICAN SOCIETY FOR ENGINEERING EDUCATION — Mechanical Engineering Division, Dartmouth College, Hanover, N. H.

June 26-28

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Applied Mechanics Division. Western Meeting, University of California, Los Angeles, Calif.

a metal ball PROBLEM?



Let STROM Work It Out For You

Whether it is a precision ball bearing or one of the other many ball applications in industry, your problem will not be entirely new. Strom has been in on many ball problems and knows the importance of the right ball for the job.

Strom has been making precision metal balls for over 25 years for all industry and can be a big help to you in selecting the right ball for any of your requirements. In size and spherical accuracy, perfection of surface, uniformity, and dependable physical quality, there's not a better ball made.

Strom STEEL BALL CO.

1850 So. 54th Ave., Cicero 50, Ill.

Largest Independent and Exclusive Metal Ball Manufacturer

BECAUSE the production and management team of the E. W. Bliss Company, Canton, Ohio learned from experience that Meehanite castings could regularly provide the reliable range of top quality properties demanded by their specifications, they operate two foundries which produce these castings for all major component parts.

The Bliss S-2 Heavy Duty Press shown is built with the following 10 major castings:

1. *Press Bed*
2. *Crown*
3. *Connections*
4. *Uprights*
5. *Slide*
6. *Bolster Plate*
7. *Bearing Caps*
8. *Flywheel*
9. *Gibs*
10. *Gears*

As can be seen from this list, the Bliss line, noted for its rugged dependability, precision manufacture, and trouble-free service makes maximum use of the uniform dependability of Meehanite castings—castings processed to provide the right combination of properties for the job.

Today as in the past, in modern designs the "TREND IS TOWARD MEEHANITE CASTINGS." Investigate the many ways they can improve your product—production—quality.

Write for our new sound slide film "Meehanite Castings Serve All Industry."

MEEHANITE®

NEW ROCHELLE, NEW YORK

Take *YOUR* Casting Problem To A MEEHANITE FOUNDRY

American Brake Shoe Co.	Mahwah, New Jersey
The American Laundry Machinery Co.	Rochester, New York
Atlas Foundry Co.	Detroit, Michigan
Banner Iron Works	St. Louis, Missouri
Barnett Foundry & Machine Co.	Irvington, New Jersey
E. W. Bliss Co.	Hastings, Mich. and Canton, O.
Builders Iron Foundry	Providence, Rhode Island
Compton Foundry	Compton, Calif.
Continental Gin Co.	Birmingham, Alabama
Crawford & Doherty Foundry Co.	Portland, Oregon
The Cooper-Bessemer Corp.	Mt. Vernon, Ohio and Grove City, Pa.
Empire Pattern & Foundry Co.	Tulsa, Oklahoma
Farrel-Birmingham Co., Inc.	Ansonia, Connecticut
Florence Pipe Foundry & Machine Co.	Florence, New Jersey
Fulton Foundry & Machine Co., Inc.	Cleveland, Ohio
General Foundry & Manufacturing Co.	Flint, Michigan
Greenlee Foundry Co.	Chicago, Illinois
The Hamilton Foundry & Machine Co.	Hamilton, Ohio
Hardinge Company, Inc.	New York, New York
Hardinge Manufacturing Co.	York, Pennsylvania
Johnstone Foundries, Inc.	Grove City, Pennsylvania
Kanawha Manufacturing Co.	Charleston, West Virginia
Lincoln Foundry Corp.	Los Angeles, California
E. Long Ltd.	Orillia, Ontario
Otis Elevator Co., Ltd.	Hamilton, Ontario
The Henry Perkins Co.	Bridgewater, Massachusetts
Pohlman Foundry Co., Inc.	Buffalo, New York
Rosedale Foundry & Machine Co.	Pittsburgh, Pennsylvania
Ross-Meehan Foundries	Chattanooga, Tennessee
Shenango-Penn Mold Co.	Dover, Ohio
Sonith Industries, Inc.	Indianapolis, Ind.
Standard Foundry Co.	Worcester, Massachusetts
The Stearns-Roger Manufacturing Co.	Denver, Colorado
Traylor Engineering & Mfg. Co.	Allentown, Pennsylvania
Valley Iron Works, Inc.	St. Paul, Minnesota
Warren Foundry & Pipe Corporation	Phillipsburg, New Jersey

"This advertisement sponsored by foundries listed above."

GAST rotary AIR MOTOR drives agitator for BONDACTOR CEMENT GUN

PROBLEM: Design to feed dry sand-cement aggregate uniformly from mixing hopper to airline of Bondactor Cement Gun.

SOLUTION: Agitate dry mixture with Gast 4 AM rotary Air Motor driven by compressor which supplies gun.

RESULT: Economy, dependability and needed flexibility in feeding from ½ to 2 cu. yds. of concrete per hour. Unit withstands rough treatment, outdoor use by contractors.

Yes — this is another of scores of design problems *solved* with Gast rotary Air Motors. If rotary air power is a possibility on *your* product, let Gast engineers review your problem. You may profit from their concentrated experience with air power, low vacuum or pressure. Remember, "Air may be your answer!" Write for details.

see our CATALOG in SWEET'S FILE

Gast Application Ideas booklet — showing 26 design problems solved — sent upon request.

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ENGINEERING ABSTRACTS

How to Use Copper Alloys In Forgings and Extrusions—Part I

Abstracted from an article by L. F. Spencer, Chief Metallurgist, Landers, Frary & Clark, New Britain, Conn. *Iron Age*, December 27, 1952.

ALL OF THE COPPER ALLOYS are extrudable; however, not all of them can be produced economically. Those alloys which are more commonly used are listed in Table I.

Size limitations of extruded shapes depend on the specific alloy and the cross-section desired. Usually, the effective size is 6 to 7 inches. The length of the extruded section is governed entirely by weight, the maximum weight for a single extrusion being approximately 180 lb.

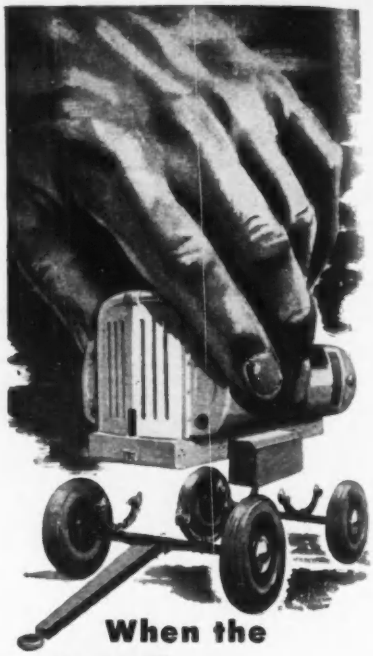
Table I—Copper Alloys for Extrusion

Metal	Average Mechanical Properties as Extruded	
	Rod and Bar	
	Tensile Strength, psi	Elongation in 2 in., pct
Electrolytic copper	32,000	40
Deoxidized copper	32,000	40
Leaded copper	32,000	40
Red brass, 85 pct	38,000*	50*
Muntz metal	52,000	45
Free-cutting brass	48,000	45
Forging brass	50,000	45
Architectural bronze	54,000	45
Admiralty metal	46,000*	65*
Naval brass	55,000	45
Leaded naval brass	55,000	45
Aluminum brass	48,000*	65*
Aluminum bronze:		
5 pct	50,000	60
8 pct	60,000	60
Cupro-nickel:		
30 pct	54,000*	35*
20 pct	48,000*	40*
High-silicon bronze(A)	53,000	70

* Tube

Extruded shapes can be made to greater thicknesses than drawn shapes, and can be designed with sharper corners. Radii and fillets on copper-base alloy extrusions can be as low as 1/64 to 1/32 inch. Dimensional tolerances vary from 0.005 in. on dimensions up to 0.125 in., to 0.035 in. on dimensions over 5 inch.

The copper-base alloys commonly



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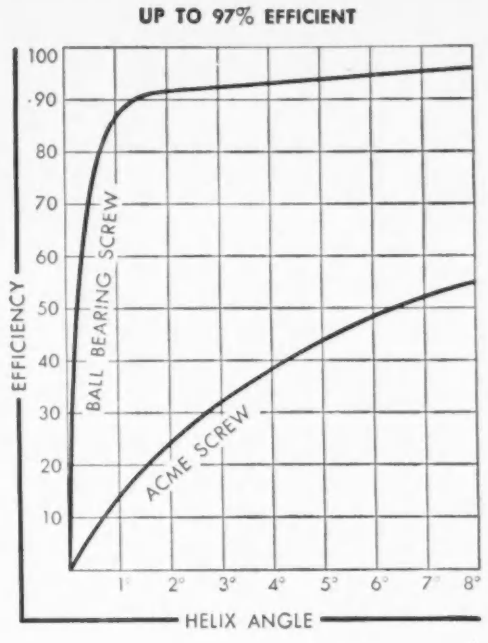

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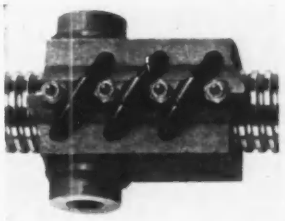
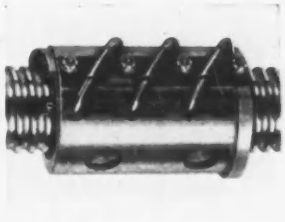
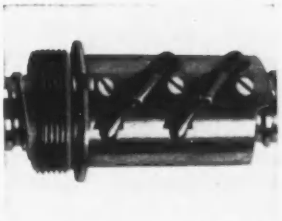


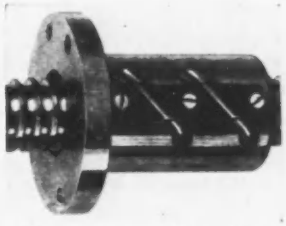
Internal or external trunnion-type nut. Three-circuit assembly.



Internal trunnion-type nut. Three-circuit assembly.



Threaded-type nut. Two-circuit assembly.



Flange-type nut. Two-circuit assembly.

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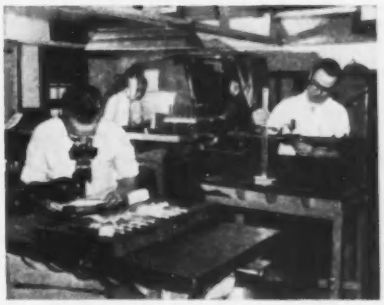

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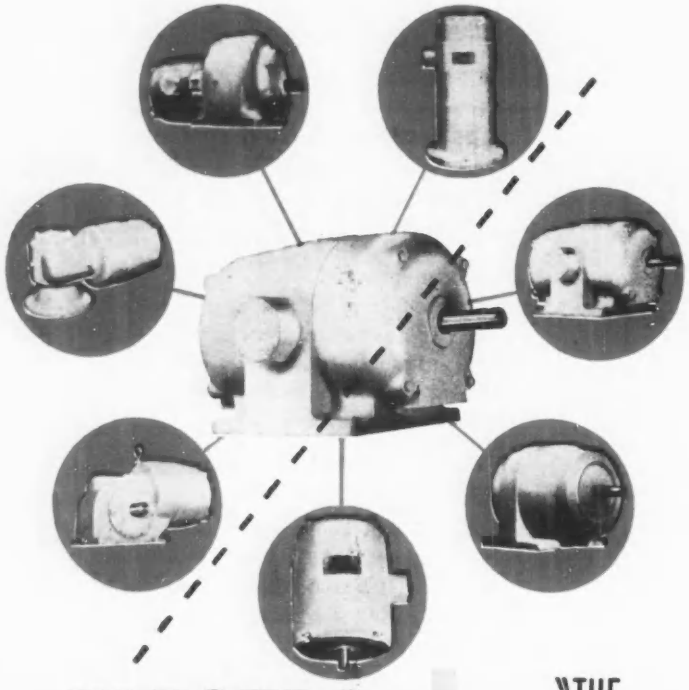

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used in the production of forgings are given in Table II. All of these alloys cannot be cold sheared, so where this is required, shearing should be specified on purchase orders.

Yellow brass accounts for the largest tonnage within the brass forging field due to its relatively low cost. This

Table II—Copper Alloys for Forging

Metal	Probable Range—Mechanical Properties	
	Tensile Strength, 1,000 psi	Elongation in 2 in., pct
Electrolytic copper	30–38	45–50
Deoxidized copper	30–38	45–50
Muntz metal	45–60	25–50
Forging brass	45–60	20–35
Naval brass	50–65	35–55
Leaded naval brass	50–65	20–35
High silicon bronze(A)	50–65	50–70
Low-silicon bronze(B)	40–55	50–70
Aluminum bronze	75–90	15–30
Manganese bronze(A)	60–75	25–45
Manganese bronze(B)	85–105	15–30
Nickel silver 10 pct leaded	65–75	20–40

composition usually has approximately 1.75 pct lead to facilitate machining. Naval brass is used where corrosion resistance is required. This composition does not contain lead and consequently it is not free machining.

Muntz metal is also a non-free-machining alloy employed where strength is an important factor. Its corrosion resistance is less than that exhibited by naval brass. The silicon-aluminum bronze is one of the strongest non-ferrous hot forging alloys on the market. It is also wear resistant, especially when in contact with steel.

Forgings

In the design of brass forging dies, the tolerances placed on the finished forging will usually dictate the life expectancy of the die. Where liberal tolerance is permitted, die surfaces can be dressed more frequently before the die must be discarded. In instances where commercial forging tolerances are used, the die is made to conform to the lower limits of the range in order to obtain maximum life expectancy.

Design factors in the forging of the copper-base alloys also contribute to the life of the die. Thus liberal fillets and radii should be specified. Usually a 1/16 in. radius in corners and fillets is satisfactory for press forgings weighing under 1½ lb. But more liberal fillets of ⅛ in. radius or more will realize increased die life. Sharp

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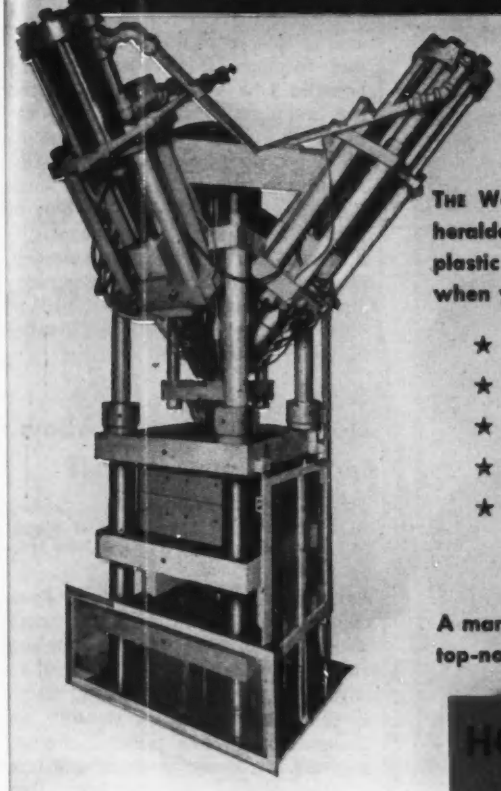

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Since the spring is enclosed by the synthetic rubber flexing member, this new "John Crane" Type 11A Seal has definite advantages on small water pump or other liquid seal applications where it is desirable to protect the spring from corrosive liquids. It also eliminates the need for expensive corrosive resistant spring material. Additional outstanding design features of this seal are:
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corners should be avoided since eventually this may lead to washing of the die in those areas, and in some cases it may lead to breakage at the corners.

Forging draft is required to permit ease of ejection of a forging. In hammer forgings, this value is usually between 3 to 7 deg, depending upon the cavity depth and the complexity of the forging. The value usually given for draft in press copper alloy forgings is between 1 to 5 deg, though this value will vary with the type of knockout employed. In general, a draft of 3 deg is the maximum needed. Shrinkage allowance for copper-base alloys is usually between 0.010 to 0.015 in. per in. A flash allowance of 0.035 to 0.080 in. is made.

How to Use Copper Alloys In Diecastings—Part II

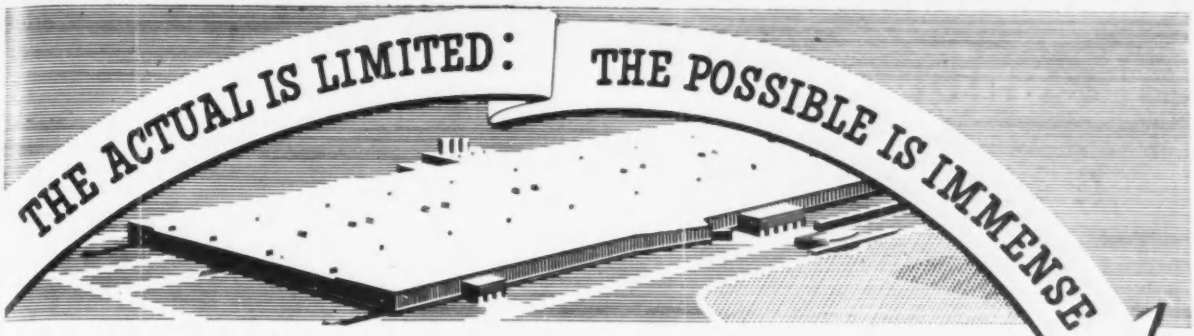
Abstracted from The *Iron Age*, January 10, 1952. By L. F. Spencer, Chief Metallurgist, Landers, Frary & Clark, New Britain, Conn.

PRESSURE DIECASTINGS made from copper-base alloys are not as extensively used as those in aluminum and zinc alloy. But they can be used to advantage where complexity of design is combined with high strength requirements. While pressure diecastings are less dense in grain structure than hot pressed or forged parts, they are adaptable to a wider ranger of design. Intricate coring does not present any special difficulty nor do heavy sections with thin webs, thin sections with reinforcing ribs, or bosses.

The basic compositions usually employed as diecast material are listed in Table I and II. Alloy A is a general purpose alloy of low cost with wide limits as to impurities. Alloy B is of higher purity and is capable of excellent castability and mechanical properties in the as-diecast condition. Alloy 2 is harder and has better physical

Table I—Copper Alloys for Diecasting

Element and quality	Composition and properties	
	Alloy 1	Alloy 2
Copper (percent)	60.0	81.50
Silicon	0.15	4.25
Lead	1.0	....
Manganese	....	0.15
Tin	1.00	....
Aluminum	0.10	....
Zinc	37.75	15.10
Tensile strength	55,000	85,000
Yield strength	35,000	50,000
Elongation	8.0	8.0
Charpy Impact	....	40
Brinell	....	170



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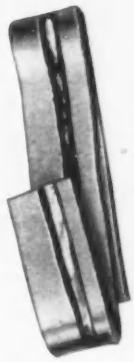

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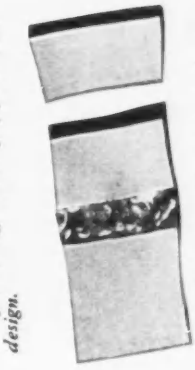

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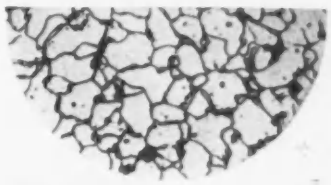
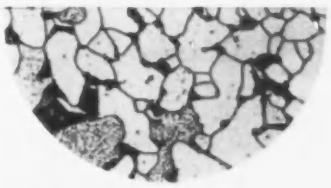
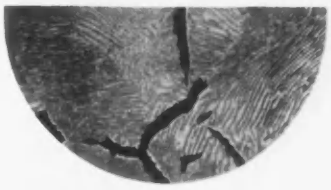


WELD METAL



MILD STEEL



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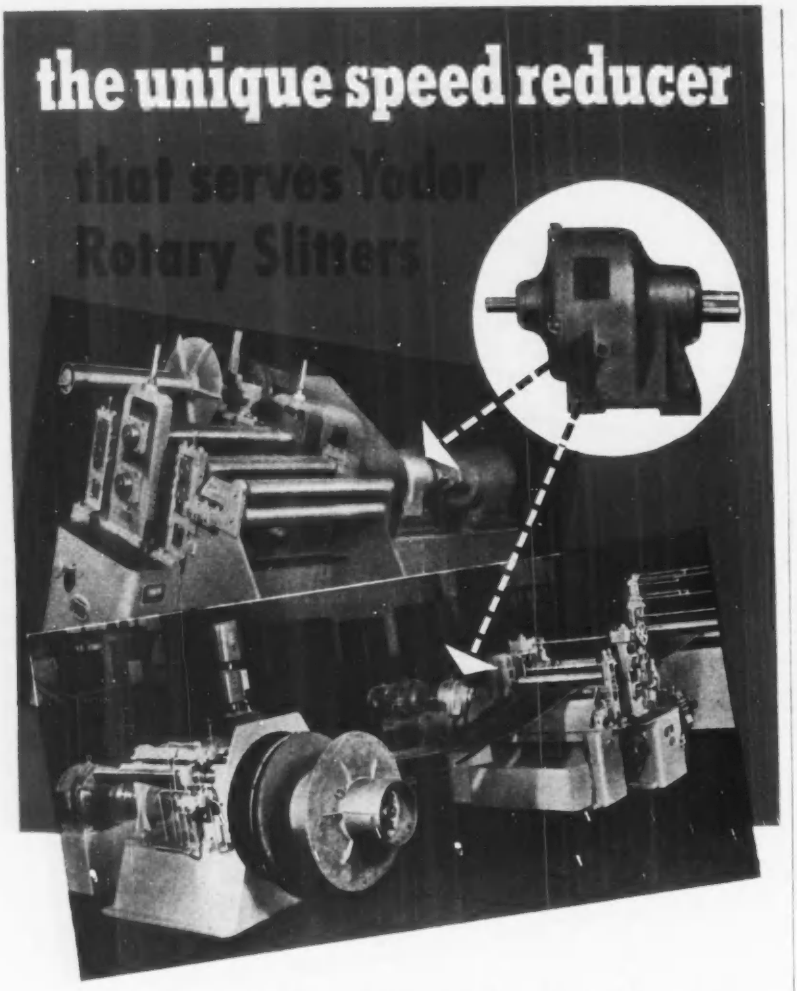

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The heart of this design is a 6-gear planetary element, free within its housing to float into the most equalized load distributing position. Even wear, automatic compensation and alignment, smooth, enduring operation are thus assured.

For requirements within the 1/100 to 85 hp range, with ratios from 1.1:1 to 50,000:1, Winsmith is the name most remembered. Information in "Save through Standardization" folder. Write.

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Table II—Copper Alloy for Diecasting

Element and quality	Composition and properties	
	Alloy A	Alloy B
Copper (percent)	57.0 min	63.0 to 67.0
Silicon	0.25 max	0.75 to 1.25
Lead	1.50 max	0.25 max
Manganese	0.25 max	0.15 max
Tin	1.50 max	0.25 max
Aluminum	0.25 max	0.15 max
Iron	0.25 max	0.15 max
Other elements	0.50 max	0.50 max
Zinc	30.00 min	remainder
Tensile strength	45,000	58,000
Yield	25,000	30,000
Elongation	10.0	15.0
Charpy impact	30	40
Brinell	120	130

properties than alloy B and finds use where resistance to wear is required.

Alloy 2 is used extensively where high strength, hardness and resistance to wear and corrosion is desired. Diecastings of this composition outwear hard materials in a number of applications, and this alloy has often replaced mild steel.

Those alloys containing appreciable amounts of lead such as alloy 1 and alloy A have improved machinability. This element results in formation of gray spots of metallic lead on the surface of the diecasting. It will contribute to hot-shortness or breakage.

Section thicknesses that can be cast will vary; sections as thin as 0.070 in. can be diecast if not over too large an area. Due to the high melting temperatures employed in the diecasting of these alloys, heavy sections of ½ in. or more are not recommended. The maximum weight of a brass diecast part is usually given at 5 lb.

Cast threads in brass are feasible provided the maximum number of threads per inch is not more than 10 and the die is parted on the thread axis. Internal threads cannot be cast.

Drafts on both cores and side walls are necessary. For the brass casting alloys, the minimum draft in inches per inch of length or diameter on cores and side walls is usually 0.020.

In the casting of holes, the minimum diameter feasible in brass alloys is approximately ⅛ in. For brass diecasting alloys, holes that are smaller than 0.186 in. in diameter need not be cored. Holes that have a diameter from 0.186 to 0.500 in. have a cored depth approximately 1½ to 3 times the diameter. In holes that have a diameter from ½ to 1 in., the cored depth will vary from 3 to 5 times the diameter. Where deeper holes are encountered, it is advisable to core a portion of the depth.

Small fillets should be used on both

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Bearing unit, with seals independent of housing, can align itself in any direction without seal distortion.

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Patented locking pin and dimple prevent rotation of outer race in housing. This eliminates housing wear, permits shaft alignment and positions unit for relubrication.

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SealMaster's cast housings combine rigid, one-piece construction with smooth streamlined appearance.

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How Can We Appraise Metals For High-Temperature Service?

Abstracted from "How Can We Appraise Metals for High-Temperature Service?" by Thomas J. Dolan, Research Professor of Theoretical and Applied Mechanics, University of Illinois, Urbana; *Metal Progress*, March, 1952.

THIS PAPER SUMMARIZES the principal observations on the factors influencing the fatigue strength of metals at high temperatures. Most of these experimental studies should be regarded as qualitative only; much analytical and experimental work needs to be done before accurate design procedures can be evolved.

Creep Versus Fatigue

A great deal has been learned during the past 100 years about the qualitative nature of the many factors affecting fatigue of metal. Even for operation at room temperatures, however, the difficulty of predicting fatigue strength of a particular member is evident from the fact that the following factors all have a definite influence on its magnitude and effects:

1. The material (including its metallurgical condition and method of processing or forming).
2. Alteration of the material by plastic action, aging, precipitation, relaxation, or recrystallization.
3. Environment (presence of corrosive or chemically active media).
4. Geometric shape of the member, and surface finish.
5. Over-all size of the member.
6. Presence of residual stress.
7. Range of stress (from minimum to maximum) and magnitude of the mean stress in the cycle.
8. Degree of biaxial or triaxial stress at the critical section.
9. Previous stress history.

Now add to this array of variables the important changes caused by a marked increase in temperature! Furthermore, due to the accompanying creep and the instability of metallurgical structures at high temperatures, the elapsed time (or frequency of stressing) must also be considered in the appraisal.

A comprehensive discussion of fatigue of metals at high temperatures

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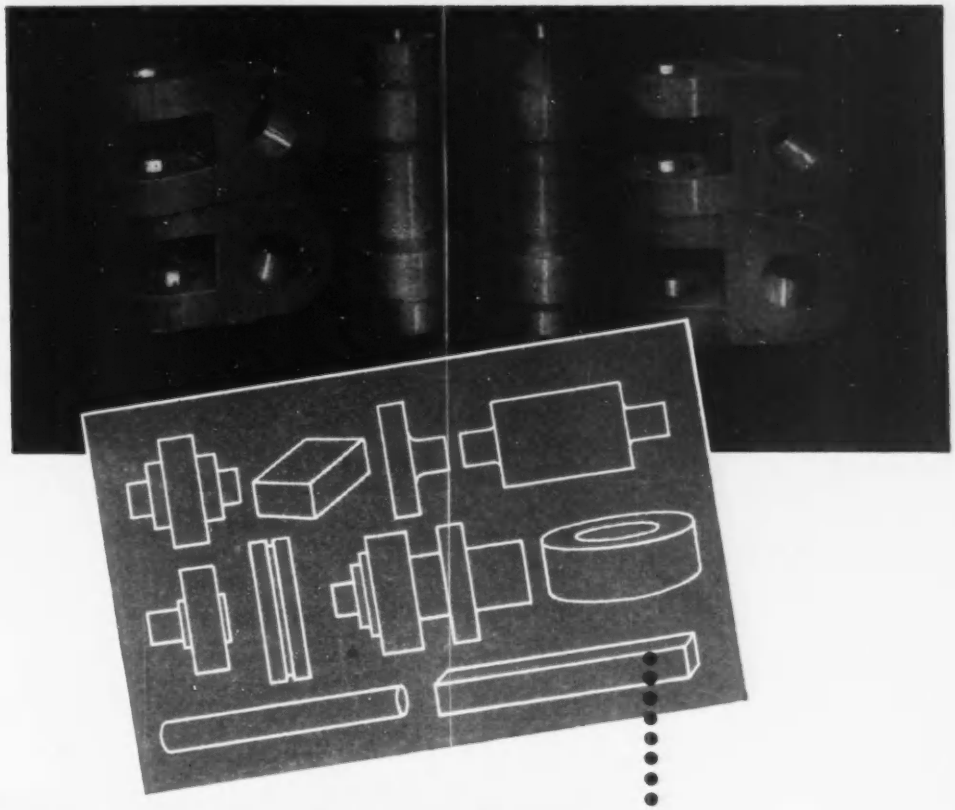

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can be divided into three broad categories.

I. Moderately elevated temperatures, below the range in which creep under steady load becomes an important factor.

II. Elevated temperatures, covering the range in which repeated stressing and continuing inelastic deformation (creep) combine to govern the phenomenon of failure.

III. Very high temperatures, for which damage by creep becomes the primary consideration.

The division between these three temperature zones is indefinite; the transitions cover broad temperature ranges whose numerical values depend on the material under consideration. We will assume that categories II and III are the fields of primary interest, since generally the fatigue behavior of steels is not markedly affected by moderate heating above room temperature; in category I above, the endurance limit might therefore be expected to vary in approximately the same manner as the static tensile strength.

Creep is a time-dependent action whereas fatigue is commonly regarded as a cycle-dependent phenomenon; fracture at high temperature may result from either creep or fatigue or a combination of the two, and the accompanying ductility may be considerably less than in short-time tensile tests. A part may sometimes be subjected to creep without the superposition of repeated stress, but above certain temperatures repeated stressing cannot be imposed without the simultaneous occurrence of creep. Thus, even under cyclic loading, creep might be primarily responsible for final fracture of the piece. This interaction may result in a total life quite different from that predicted.

In ordinary fatigue tests of steels at room temperature, results are not appreciably affected by varying the frequency of stressing over a fairly wide range. However, under simultaneous cyclic stressing and corrosion, or cyclic stressing at elevated temperature, the accumulation of damage depends on time as well as on the number of cycles of stress. The time-dependence of damage (by creep or by corrosion) may explain why there seems to be no definite endurance limit in tests incorporating these variables—the S-N diagram is found to be a downward sloping line, even after hundreds of millions of stress cycles.

If the stress frequency is relatively low, the testing time may be long, whereupon considerable time is available for damage by creep, and specimens may fail under fewer cycles of a given stress, in contrast to high stress

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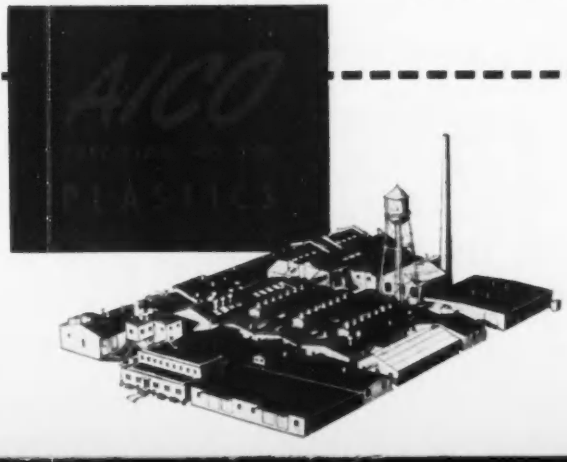

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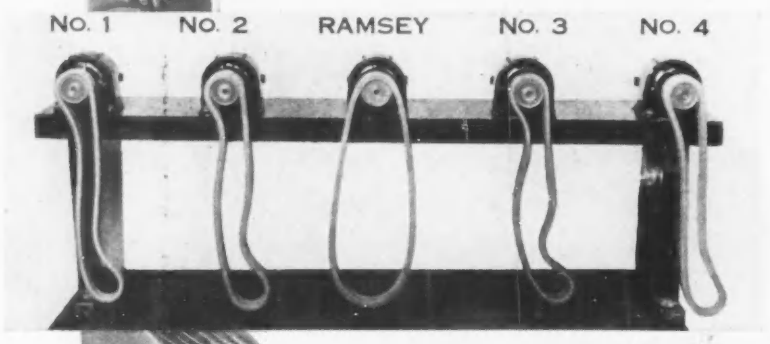

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frequency. Furthermore, the longer time of test may markedly alter the strength characteristics of the material if precipitation hardening or aging occurs at the test temperature.

Stress History

In a number of applications such as gas turbines, superchargers and combustion chambers, important components operate at high temperature and under a cyclic or repeated load superimposed on a static load (such as a vibrating turbine blade carrying centrifugal loads from the high speed of rotation, plus bending or torsion from the gas impulse). In many instances the primary stress history may be suitably approximated by a sine curve superimposed on a steady or mean stress. This can usually be reproduced by carefully designed testing machines with provision to alter the mean load and alternating load to desired values.

In other important applications, however, the complex stress history may be nonrepetitive and hence cannot be simulated by any simple laboratory procedures. Often, the existing test data were obtained under conditions having only the vaguest relation to such complex conditions as met in an engine or turbine blade.

For elevated-temperature tests a distinction should be made between the applied load, which is controlled, and the stress, which is computed. (For example, the stress can be computed with accuracy only for axial load tests.) The calculated stresses imposed upon a flexural or torsional member in a fatigue test at high temperature represent only nominal values, not true stresses. The formulas upon which these calculations are based assume elastic conditions. Yet high-temperature creep invalidates this assumption. Where creep is present and elapsed time influences the strength and deformational characteristics, the real behavior of the metal cannot be adequately predicted by linear stress-strain relationships independent of time. Any specific design is further complicated by temperature gradients, stress raisers (notches or abrupt changes of section) and by metallurgical instability. Hence, no quantitative solution of these complex problems has been evolved.

Method of Testing

The fatigue test and the creep test represent only two of the various criteria arbitrarily applied for appraising an alloy for high-temperature service. The various laboratory techniques include:

1. Short-time static properties.

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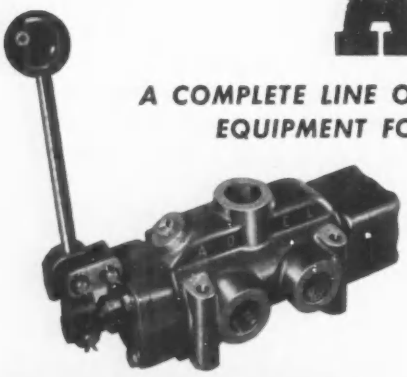

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2. "Time-to-rupture" under constant load.

3. Creep rates or total creep under constant load.

4. Stress relaxation under constant total strain.

5. Fatigue life or fatigue strength for alternating loads or for combination of a mean load and an alternating load.

It is doubtful that any single test provides a simple or accurate index of the qualities most desired. In the higher temperature ranges, for which creep is pronounced, it usually is necessary to give some kind of weighted consideration to the results obtained from several types of test. In any case the results constitute an estimate based on as many tests as may be practical.

Stress Raisers

Little data are available on the reduction of strength caused by "stress raisers", or the manner in which they affect the creep or fatigue characteristics of heat resisting alloys at high temperature. It is practically impossible to fabricate a structure without changes of section that lead to localized stress concentrations. Details such as spot welds, stamped holes, minute rubbing of adjoining components, and inadequate fillets may also be responsible.

At ordinary temperatures these stress raisers are the primary "sore spots" affecting the fatigue strength of a member and its life to fracture. Presumably the same would be true at elevated temperatures if fatigue were the sole controlling factor. However, since creep is a function of the stress level, large deformations might develop in the neighborhood of the stress raiser, thereby relieving the localized concentration of stress. Under conditions combining a high mean stress with simultaneous alternating cycles of stress, the severity of the stress raiser might be less than at room temperature. On the other hand, if completely reversed cycles of loading occur at elevated temperatures, it is difficult to predict whether creep would be of any assistance in relieving the localized stress, unless the cyclic frequency be extremely slow. Any creep which occurs under a compressive stress would tend to be counteracted by the subsequent reversed creep during the other half of the load cycle. If the loads are completely reversed with high frequency, the range of strain (and perhaps the corresponding range of stress) in any one cycle might not be materially affected by the creep conditions which occur during the test.

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Cold hands put a "frostbite" on production efficiency in the 1890's. Today, efficient unit heaters force billows of warm air to every corner of even the largest plants. The temperature stays up . . . so does worker efficiency.

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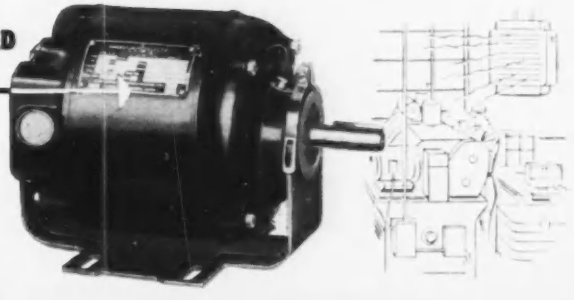

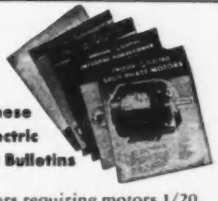

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- ☐ M116-F Jet Pump
- ☐ M116-G Blower

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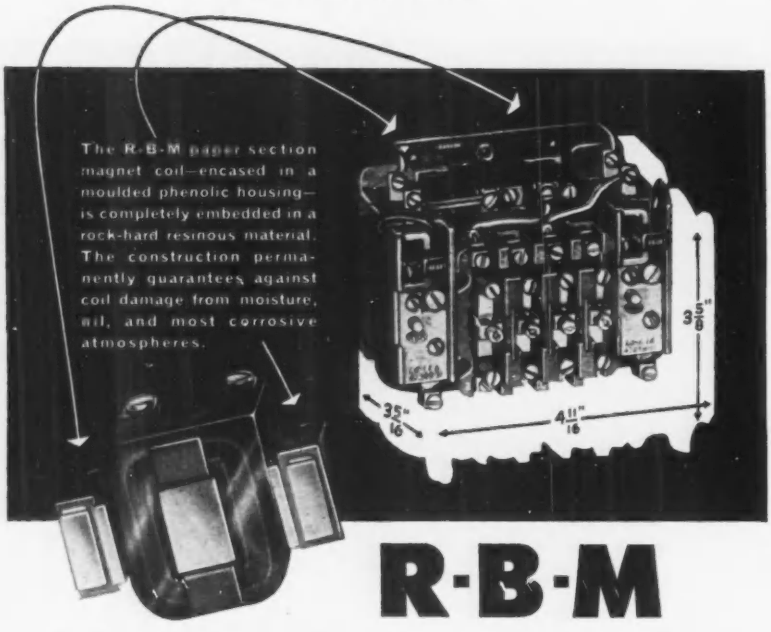
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MANUAL AND MAGNETIC ELECTRIC CONTROLS
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Sans, Souci

Ad Libbing by the Editor

Personal dignity is a great asset. It is impossible to define and for some it seems impossible to achieve. But everyone is able, if he so desires, to add to his personal dignity. To do so costs nothing in dollars but often it spells the difference between poverty and affluence. Yet the poorest man can be richest in personal dignity.

The personal dignity and standing of the head of a department usually goes hand in hand with his authority. If the department head, without protest, permits others, associates or superiors, to "swing their weight around" in his department, he will soon find that he has lost the respect of the men under him. Every man should guard zealously the rights, privileges and authority of his position.

Once I heard a great manager say, "There are always men in every organization who will peck away at the foundations of those in higher authority. They will chip off a bit here and there, usually by usurping just a bit of authority or modifying orders. When they get everything ready and the opportunity presents itself, they throw out their tentacles like an octopus and demand of management that their's shall be the position of higher authority. It often works that way."

All of which reminds me of a technique that is used frequently. There are those who climb the ladder of success to dizzying heights by the simple process of criticizing accomplishments of others. If they were called upon to do the simplest thing in their chosen field, they would make an unholy mess of it. But they are past masters at showing in a very dramatic fashion how a given finished job could have been done better.

Some place or other I read the story of the unveiling of an equestrian statue in presence of the king, his courtiers, and the sculptor. One of the courtiers, or whatever else one might like to call them, criticized numerous details of both horse and rider. The horse's right leg was too high, his head was held too low, his tail was too short and so on and on and on. The sculptor then said to the king:

"Your Majesty, I beg of you to permit me to again put the canvas tent around this statue so that I might have the opportunity of rectifying all of the errors pointed out by your courtier."

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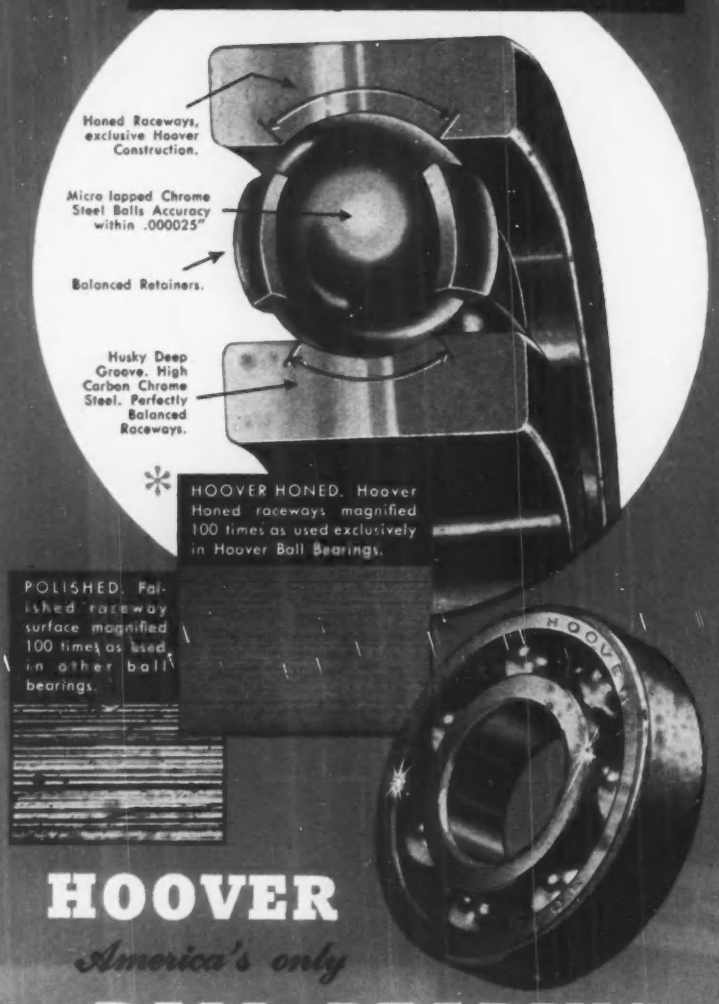
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weeks there could be heard the noise of the chipping hammer inside the tent that veiled the statue. Finally came the time for the second unveiling and again the king, his courtiers and the sculptor were present.

After the statue had been unveiled the same courtier continued with his criticism:

"Yes, now the horse's right leg is no longer too high. In fact perhaps it is slightly too low. But the added tilt to the horse's head is just perfect and the slightly longer tail makes it just right."

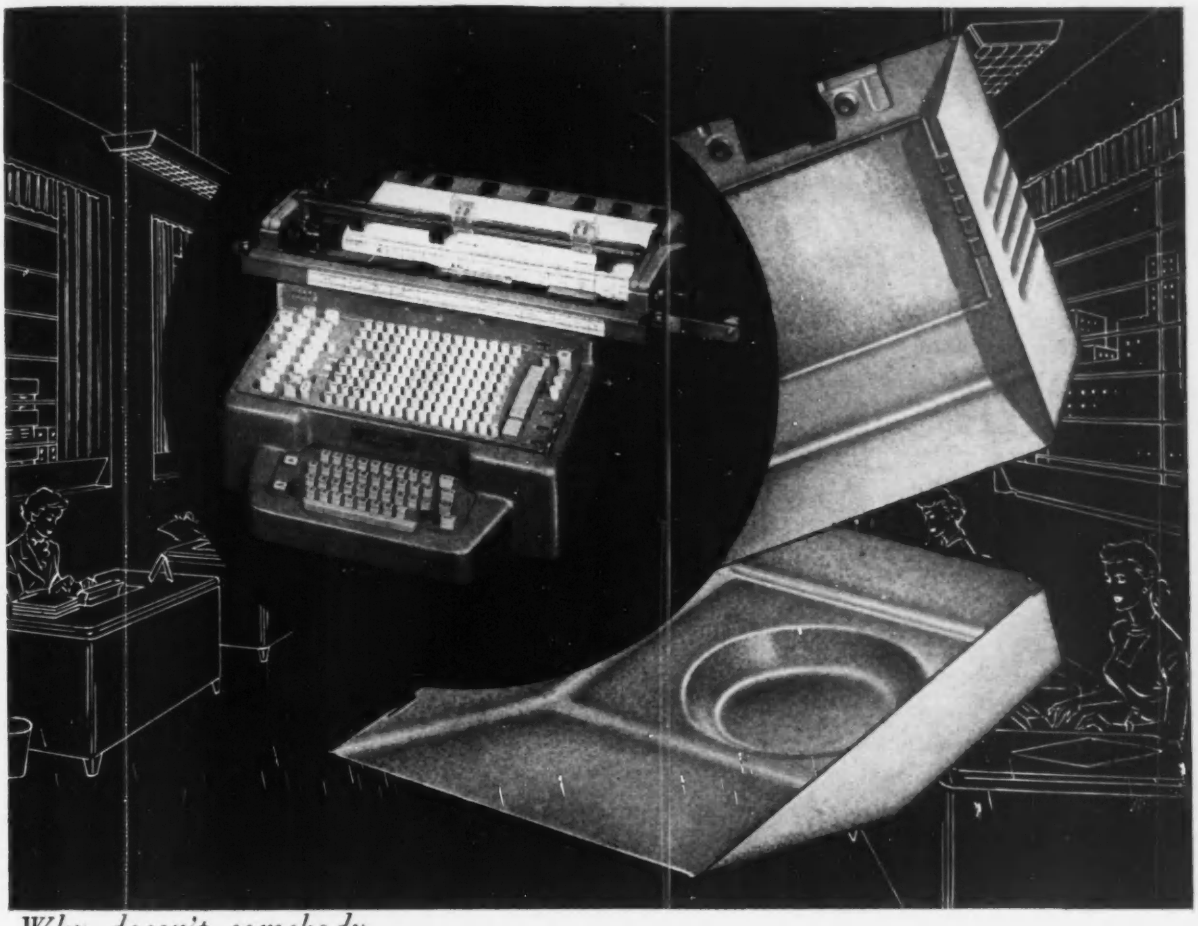
After the criticisms had been completed the sculptor turned to the king and said, "Your Majesty, this statue is exactly the same as it was when it was first unveiled. It is cast in bronze and it is impossible for anyone to alter it in any detail. For the past two weeks I have been merely pounding on my chisel to make it appear that I was altering the statue to conform to the courtier's criticisms. But as I explained, the statue is still exactly the same."

Henry L. Gantt, pupil of Frederick Winslow Taylor and one of the early management consultants, made this statement, "The authority to issue an order involves the responsibility of seeing to it that it is properly executed." The implication is that if you don't know how a job should be done or if you are not in a position to know whether a job has been done correctly or not, you haven't the right to give the order. Under such circumstances you should simply delegate to a properly equipped person the responsibility of getting the job done. That is the way modern business operates. This thing of merely being a kibitzer on the job is extremely distasteful to those who have the responsibility of getting the job done.

I just had a telephone conversation with my friend Mr. E. Hurst who has recently been promoted to president of United Cotton Products Company of Fall River, Massachusetts. He mentioned something that he had seen in "Sans, Souci" last October concerning the futility of producing to a degree of accuracy and quality that had no commercial value. Mr. Hurst told me that it reminded him of the following little ditty:

"Only a thousandth," the machinist said,
As he slowly shook his head.
"Only a thousandth, a mere nothing at all,
But I took it off, now it's too damn small."

Well here is hoping that this column is not too small for the space it must fill. —G.F.N.



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OUR READERS SAY

Pneumatic Cylinder Seals

To the Editor:

At present we are engaged in an experimental project wherein we intend to use a pneumatic cylinder and piston at extremely high speed, comparable possibly to an air compressor.

In this connection we are seeking any possible information as to the type of seals we might at least experiment with, since our problem will be mainly friction due to high surface speed.

Any technical data of surface speed allowable with different types of seals or piston rings together with possible suppliers would be most welcome.

—WILLIAM F. HOLICKY
Lempco Products, Inc.

Ed—We are sending reprints of the following articles that have appeared in PRODUCT ENGINEERING recently:

1. Mechanical Seals — Theory and Criteria for Their Design.
2. Which Shaft Seal?
3. Design Recommendations for O-Ring Seals.

Round Bar Slides

To the Editor:

I am anxious to get some information regarding round bar slides which are used on a great many machine tools instead of the dovetailed slides. And I wonder if any of your editors could give me any information as to where I could read up on these. I would like to know something about the comparative costs between a bar slide and a dovetailed slide, and whether special bars have to be used. Are they hardened, etc.?

If there have been any articles on the subject, I would appreciate being told about them. —EDWARD BLAKE
Edward Blake Company

Ed—We are not experts by any means on round bar slides, but here is the consensus of the staff.

The type of material and whether the bar would be hardened or not would, of course, depend entirely on the requirements of the job. For most cases, you would want to at least case harden the bar, although if loads were

How in the world would **you** have solved these connector problems?

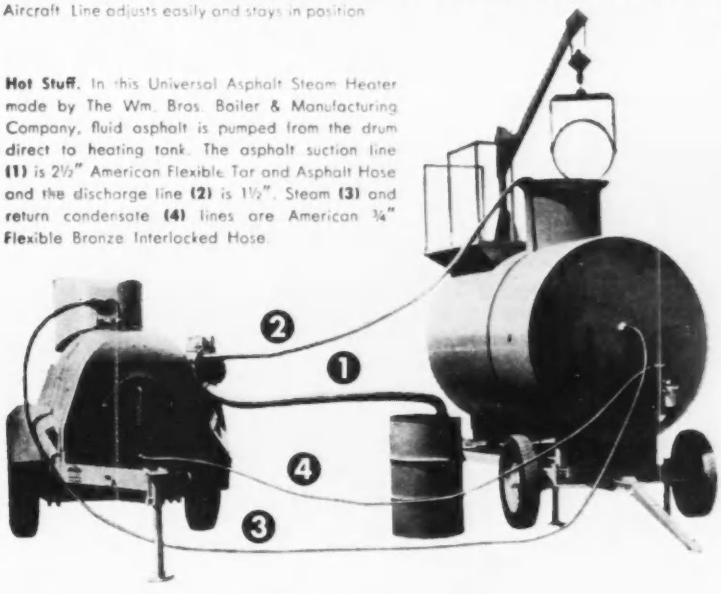
Coolant gets a new twist. A quick twist, and American Flexible Metal Tubing conveys coolant to just the right spot on this special lathe which machines jet engine parts at Pratt & Whitney Aircraft. Line adjusts easily and stays in position.

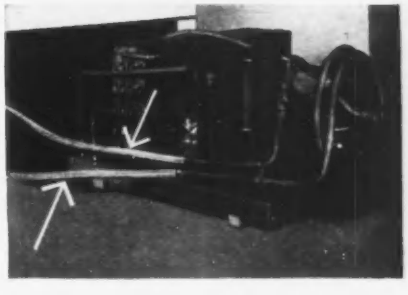
Would you have relied on costly, clumsy, rigid piping? Thrown up your hands? Or – like the resourceful designers of these three machines – would you have used flexible metal tubing? In each case American Flexible Metal Hose or Tubing filled the bill . . . and cut operating costs.

Your product, too, may need versatile, flexible American Metal Hose. If it must move, bend, or vibrate, let us show you the right connector...designed to absorb vibration, connect moving lines, or to be assembled in close quarters, while resisting heat, cold, pressure and corrosion in conveying liquids, gases or semi-solids. Write for Bulletins SS-50 and CC-300 which give technical details and many application histories. The American Brass Company, American Metal Hose Branch, Waterbury 20, Conn. In Canada: The Canadian Fairbanks-Morse Company, Ltd.

52255

Hot Stuff. In this Universal Asphalt Steam Heater made by The Wm. Bros. Boiler & Manufacturing Company, fluid asphalt is pumped from the drum direct to heating tank. The asphalt suction line **(1)** is 2½" American Flexible Tar and Asphalt Hose and the discharge line **(2)** is 1½". Steam **(3)** and return condensate **(4)** lines are American ¾" Flexible Bronze Interlocked Hose.





Pull-out is a push-over to repair. Tyler Fixture Corp. neatly solved the problem of permitting quick inspection and easy repair of the refrigerating unit in their freezers. Entire unit pulls out, yet refrigerant lines remain connected – thanks to American Seamless Flexible Bronze Tubing.

wherever connectors must move

ANACONDA

American **FLEXIBLE METAL HOSE AND TUBING**

FOR Westinghouse!

Westinghouse Electric Corp. recently required a part for use on oil circuit breakers. Their rough blueprint called for a link composed of three separate units which had not only to be machined, but welded together.

Atlantic's engineers suggested a design that resulted in a part cast in ONE PIECE from Atlantalloy #31 High Tensile Manganese Bronze . . . a dependable engineering material that is stronger than many steels. This one piece casting eliminated the involved machining, welding and finishing steps—and consequently afforded a substantial saving over former costs.

Write for a copy of "Quality Precision Castings for Industry" today. This booklet shows how the plaster mold process cuts production costs and includes specifications on Atlantic's alloys.

ATLANTIC Established 1937
CASTING and ENGINEERING CORP.
721 Bloomfield Avenue • Clifton, N. J. • PRescott 9-2450

not high, this would not be necessary.

There are some machine tools made with such type slides, particularly a type of milling machine which instead of a dovetailed slide on the overarm utilizes a round bar which slides through the bushings in the upper housing of the machine. However, the major use of such slides is on woodworking machines where accuracy requirements are not at rigid as they would be on metal-working equipment.

Naturally, with such a type of slide you are bound to get some play. Insofar as bushing materials and bar stock are concerned, catalogs of suppliers or steel companies will give you all the information that you would want. We had a brief article about a year and a half ago on precision bearings for linear movements and we are sending you tear sheets of that article.

If you can give us some specific information about your problem, perhaps we can answer it or at least locate someone who will be able to supply the information and data you need.

Complaint Against the Decimal System

To the Editor:

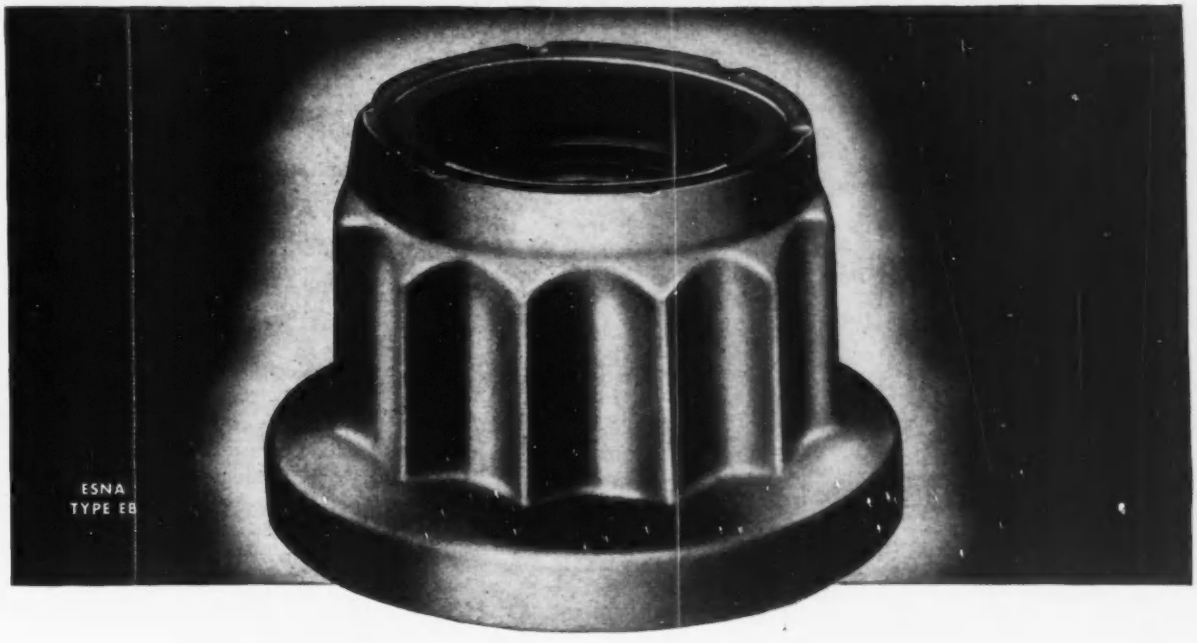
The articles in PRODUCT ENGINEERING, "Organizing a Computer Center" (Jan. 1952, p. 136) and "Operation and Application of the Differential Analyzer" (April 1952, p. 164), contrast how much scientific study has been incorporated into these computers while we, aside from these machines, continue to use without question the primitive system of numeration based on our ten fingers (digits), the decimal system, which is an awkward one when some commonly used fractions are converted into decimal fractions.

The duodecimal system of numeration, based on powers of twelve and one-twelfth, is handier for measuring length, area, volume, weight, circle, and time. In calculation it is more accurate, efficient, and economical. It is better than the metric system. Prime numbers and factors are easier to determine in it.

Consider the most commonly used conversion table in the U. S.—multiples of $\frac{1}{64}$ into decimal fractions. All odd multiples of $\frac{1}{64}$ require six decimals but require only three duodecimal places—thus, $\frac{1}{64}$ is expressed .015625 decimally and .023 duodecimally; $\frac{1}{3}$ is expressed .33333+ decimally and .4 duodecimally. A duodecimal micrometer would be more accurate. The factors of 12 (2, 2, 3)

High Strength DOUBLE HEX NUT

CUTS SIZE...WEIGHT OF AIRFRAME COMPONENTS



—the famous Self-Locking Red Elastic Collar

***protects permanently against* IMPACT! VIBRATION!**

The NEW ESNA HIGH Strength-Double Hex Nuts have been scientifically engineered to accomplish distribution of thread load with minimum weight and wrench diameter. They develop 185,000 psi. min. in NAS high strength aircraft bolts, and are completely interchangeable with existing internal wrenching nuts; yet this unique double hex design saves 66% in weight and 50% in height, compared to the old internal wrenching types. These savings in weight and clearance gain greater importance when multiplied by the additional savings in the size and weight of component parts or fittings which the new design makes possible to employ.

Because of their light weight . . . extra safety . . . easy field identification . . . and reduced wrenching area, ESNA Type EB Nuts are accepted as standard for all high tensile applications by airframe manufacturers. Also, of great importance maintenance-wise is the fact that no special wrenches are required—any socket wrench will do.

Further—like all Elastic Stop Nuts—the NEW High Strength Nut remains self-locking in both fully seated and positioned settings.

HERE'S A CHALLENGE: Send us complete details of your toughest bolted trouble spot. We'll supply test nuts—FREE, in experimental quantities. Or, if you want further information, write for literature. Elastic Stop Nut Corporation of America, Dept. N4-62, Union, New Jersey. Representatives and Agents are located in many principal cities.

ESNA
TRADE MARK

ELASTIC STOP NUTS

HIGH TENSILE

ANCHOR

HIGH TEMPERATURE

SPLINE

CLINCH

GANG CHANNEL

NYLON CAP

NYLON AND FIBER INSERT TYPES ARE QUALIFIED TO SPEC. AN-N-5

Available

for the first time...

a Full-Color Sound Film

STEEL WITH A THOUSAND QUALITIES

Scientific schools and groups of designers, engineers, metallurgists and technical societies can *now* secure the *free* use of this full-color sound film, the first produced in the steel foundry industry. Available in 16 mm prints, the film is a 37-minute tour of the modern plant of Lebanon Steel Foundry. The camera follows jobs from the blueprints on the project engineer's desk through steps of production to show, finally, a few of the many important uses of Lebanon quality Steel Castings. Write for information on this exciting and educational film.

LEBANON STEEL FOUNDRY
Dept. C, Lebanon, Pa.
In the Lebanon Valley

LEBANON
ALLOY AND STEEL
CIRCLE L **castings**

are mechanically handier than those of 10 (2, 5). JOHN E. WHITESIDE
The Duodecimal Society of America

Ed—We thought PRODUCT ENGINEERING readers might be interested in some of the details of the duodecimal system because they have been discussed for many years in mathematical circles.

The duodecimal system uses 12 as a base and requires two additional symbols: X, dec, for the quantity after nine; and ε called el for what is now 11. The quantity one dozen is expressed 10 and called do. The quantity one gross, a dozen dozen (now 144) is expressed 100 and called gro.

Place value. In the new system the quantity 265 would represent 5 units, plus 6 dozens, plus 2 gross—the quantity we normally express as 365(5 + 6 x 12 + 2 x 144 = 365).

To add. Place value is the key to dozen arithmetic, and you add to a dozen before carrying one. Examples:

54	136
31	694
96	3ε2
15ε	1000

To multiply. Complete multiplication table, base of 12:

	2	3	4	5	6	7	8	9	X	E	10
2	4	6	8	X	10	12	14	16	18	1X	20
3	6	9	10	13	16	19	20	23	26	29	30
4	8	10	14	18	20	24	28	30	34	38	40
5	X	13	18	21	26	2E	34	39	42	47	50
6	10	16	20	26	30	36	40	46	50	56	60
7	12	19	24	2E	36	41	48	53	5X	65	70
8	14	20	28	34	40	48	54	60	68	74	80
9	16	23	30	39	46	53	60	69	76	83	90
X	18	26	34	42	50	5X	68	76	84	92	X0
E	1X	29	38	47	56	65	74	83	92	X1	E0
10	20	30	40	50	60	70	80	90	X0	E0	100

Of course addition during the multiplication process is done as indicated above.

THE DO-METRIC SYSTEM.

The Mechanics Scale

Twelve points	equal	1 line
Twelve lines	equal	1 inch
Twelve inches	equal	1 foot

The Basic Scale

Twelve kails	equal	1 quan
Twelve quans	equal	1 palm
Twelve palms	equal	1 yard

The squares and cubic measures are directly derived from these units.

Volumes and Weights

The palm is 3 in.; the cubic palm is the do-metric pint; and the weight of this pint of water is the do-metric

"Joe, who can make these small parts to our close 'specs'?"

"Torrington can, Tom. They have the experience and equipment to maintain precision tolerances on any quantity of small metal parts."

Small precision parts often take more production time than can be spared. That's why many leading manufacturers have turned over their parts problems to Torrington. Using the latest automatic and semi-automatic equipment, our Specialty Department produces hundreds of thousands of parts every day to the exacting specifications of hundreds of customers. These companies—some of them Torrington customers for over 40 years—have learned that they save both time and money when their small metal components are made by Torrington.

Why not send us a blueprint or sample of *your* small parts? We will quickly tell you how little it costs to have uniformly accurate components.

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554 Field Street • Torrington, Conn.

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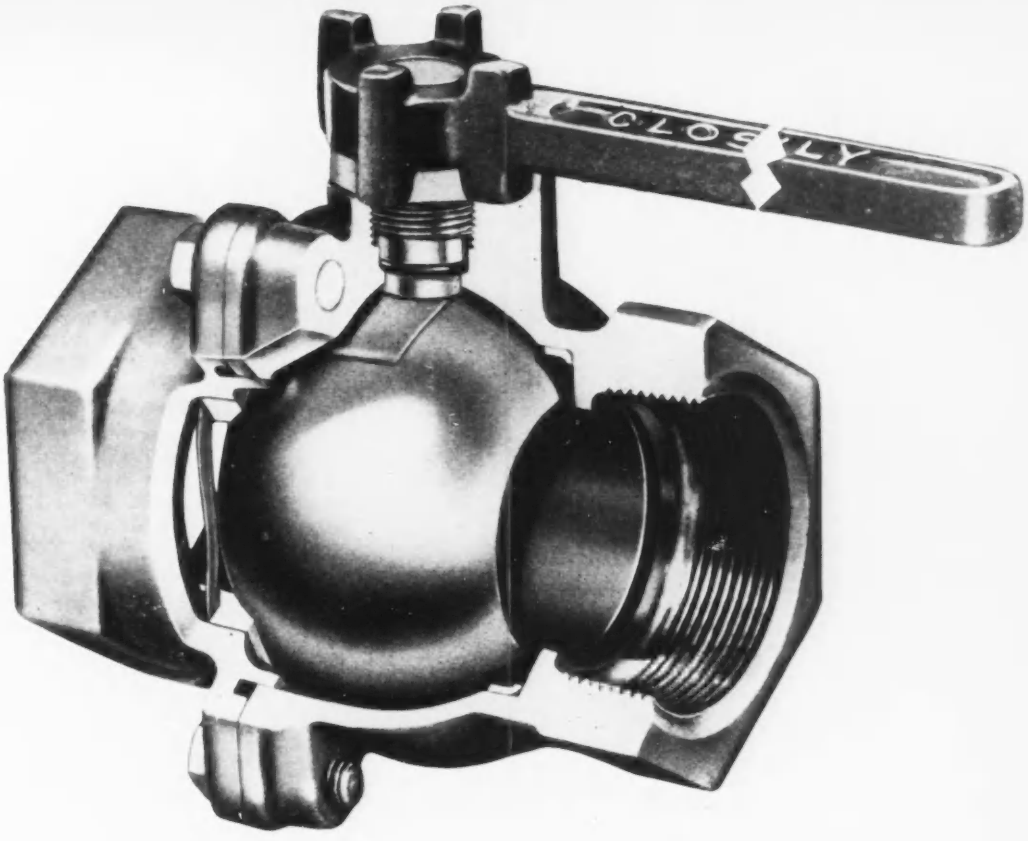

NEW BALL VALVE

gives you more of what you want in a valve

Full round flow . . . as full as if there were no valve in the pipe at all. Handles fluids with minimum friction loss . . . without turbulence.

Quick opening . . . Quick closing . . . even under full pressure. Needs only an easy quarter turn.

Resists wear longer . . . chrome-plated floating bronze ball is extremely resistant to scratching, pitting, abrasion.

Stays leakproof . . . When valve is in closed position, pressure of fluid automatically positions ball against synthetic rubber seat to form a tight seal.

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Among the many satisfied users of Rockwood Ball Valves are:

Libbey-Owens-Ford Glass Company
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Send For Free Bulletin, "New Rockwood Ball Type Valves," containing detailed information.

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ROCKWOOD BALL VALVES

ROCKWOOD SPRINKLER COMPANY

106 Harlow Street, Worcester 5, Mass.

Shims stamped from LAMINUM® look like solid metal but actually are made up of layers of .002 or .003 inch brass or steel. The laminations are solidly bonded together, over their entire surfaces.

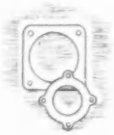
when a shim is

LAMINATED

here are the advantages you get:

REDUCED MACHINING COST

You machine only to easy tolerances. The laminated shim is *adjustable*—you simply peel laminations of .002 inch brass or steel with a penknife—to get exactly the spacing you need. You cut costs without sacrificing quality.



SIMPLIFIED USE:

Shims come to you in one "pack" for each application. They are precision-stamped to your exact specifications. No counting, no stacking, no miking. Gauge is always known. No dirt or grit can lodge between layers.

SPEEDED PRODUCTION:

Final fitting can be done right at the job. You don't have to take parts back and forth for further machining, grinding or filing. No special skill required. The laminations adjust spacing quickly, easily.

ADDED SERVICE FEATURE:

Throughout the life of the machines you produce, the simple removal of a shim lamination provides a unique adjustment for the take-up of wear. Original clearances can always be restored.

SEND TODAY for our Engineering Data File

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THE SOLID SHIM THAT [pulls] FOR ADJUSTMENT

LAMINATED SHIM COMPANY, Inc.

1406 UNION STREET GLENBROOK, CONN.

CUSTOM SHIMS STAMPINGS SHIM STOCK

pound which is 2½ percent less than the avoirdupois pound.

Do-Metric Weight

Twelve carats	equal	1 gram
Twelve grams	equal	1 ounce
Twelve ounces	equal	1 pound

Liquid Measures

Twelve dribs	equal	1 dram
Twelve drams	equal	1 founce (fl oz)
Twelve founces	equal	1 pint

Miscellaneous:

The mile is 1000 yd.

The cubic yard holds 1000 pints or 1 Tun, which weighs 1000 pounds or 1 Ton.

Do-metric temperature scale conforms to the usual pattern with 100 deg between the freezing and boiling points of water.

We're interested in hearing what other PE readers think of this system for counting and measuring.

Shop Colors

To the Editor:

Would you please forward at your convenience whatever information you have available on the use of color industrially such as painting of machinery and industrial plants.

An engineer associate advised me that you have released some interesting information on this subject during the past year—David H. Flanagan
Thompson Aircraft Tire Corporation

Ed—We are sending you a reprint of the article "How to Plan Product Colors," which appeared in the August 1951 issue of Product Engineering and an *American Machinist* article titled "How to Use More Color in the Shop."

Visual Training Aids

To the Editor:

I am very much interested in knowing of a source of information concerning the design and construction of visual aids used for classroom and sales instruction. They are also sometimes called animated models and are frequently used for demonstrating the action of hydraulic, mechanical and electrical devices and circuits.

The models which I have in mind are often made of wood, plastics and metal, but usually are built up on a board.

It is my understanding that someone wrote a book describing visual aids, but I have looked in many catalogs of various publishers, including yours, to no avail. Possible you know of

articles on the subject, or government bulletins. It seems that many models are being used by the Air Force, the air lines, and industry.

—J. G. WILLIAMS
Cincinnati, Ohio

Ed—We suggest you write to Commander Joseph Graham, Special Devices Center, United States Navy, Sands Point, New York. You will be interested in the article on page 186 of this issue of PRODUCT ENGINEERING.

Casting Impregnation

To the Editor:

In the February 1952 issue of PRODUCT ENGINEERING on page 193, appeared an article on the impregnation of castings with thermosetting copolymers.

This subject is most interesting to us as we manufacture a complete line of diaphragm-operated steam and water control valves in association with other equipment and one of our constant sources of worry is porosity in castings, mainly non-ferrous. Any information as to the supply of this product or an analysis of the actual thermosetting copolymers and a detailed account of the actual sealing procedure, would be greatly appreciated.

We trust it is possible for you to obtain this information and look forward to your early reply.

A. J. MCGOWEN
Wilcolator Manufacturing Pty, Ltd.
Melbourne, Australia

Ed—Additional information is available from the Western Sealant Co.

Blank Feeds

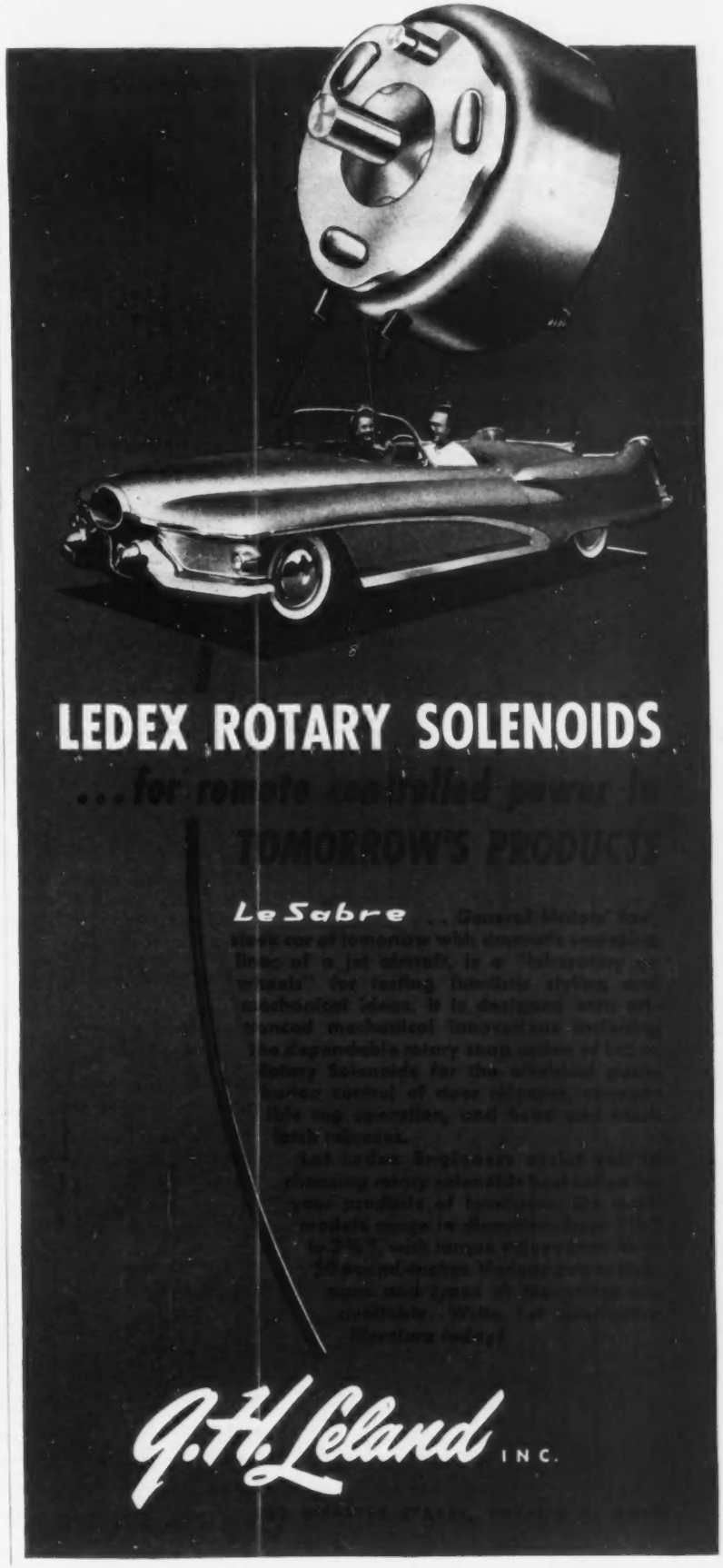
To the Editor:

We have a problem in connection with the feeding of metal blanks into high speed automatic transfer presses. The blanks are in the form of round brass disks 3.53 inches in diameter.

We have seen several types of blank feeds but it occurred to us that you might have published, prior to the time we subscribed to your publication, some information covering the various types of blank feeds which might be helpful to us. —R. A. LIVINGSTON
Tubing Seal Cap, Inc.

Ed—The only thing that we have run recently on automatic feeding is the article "Feeding, Sorting, and Counting Mechanisms." We're sending you tear sheets of that.

But a great deal of work has been



for valving corrosive and "hard-to-handle" fluids . . .

HILLS-McCANNA

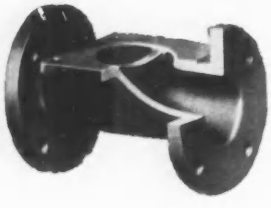
offers over 20,000 different "custom-made" assemblies on a standardized basis

32 standard operators

Methods of operation for Hills-McCanna Valves include handwheel and lever operators, sliding stem, air and hydraulic cylinders, diaphragm motors and electric motors in a variety of types.

14 standard diaphragms

Diaphragms, the heart of Hills-McCanna Valves, are offered in the widest choice to best suit your individual needs; 5 types of rubber, 3 of Neoprene plus Hycar, butyl, Tygon, Compar, special polyethylene and Kel-F.



48 standard body materials

Bodies for Hills-McCanna valves are furnished in cast iron, with or without such linings as rubber, glass, lead, etc.; in any machinable alloy or in such materials as Karbate, stoneware, porcelain, etc.

By offering such a broad selection of operators, diaphragms and bodies, Hills-McCanna is able to furnish so many standard combinations that the user is in the position of being able, in most cases, to find the exact valve that best fits his individual requirements. There is virtually never any need to adapt to your service a valve developed for someone else's needs.

The 36 page catalog No. V-52 gives full details on all Hills-McCanna Valves. Write for your copy. HILLS-McCANNA CO., 2444 W. Nelson St., Chicago 18, Illinois.

HILLS-McCANNA

saunders patent diaphragm valves

Also Manufacturers of Proportioning Pumps

Force Feed Lubricators • Magnesium Alloy Castings

done on this particular problem by the Syntron Company, 1938 Black Street, Homer City, Pa. They also have a branch office at 8413 State Street, South Gate, California, which is not far from San Gabriel. We suggest that you contact them.

Meetings Wanted

To the Editor:

I am interested in receiving information concerning seminars, forums, or conventions to be held in the near future on Production Methods, Control, or Engineering.

Since your magazine has this phase of manufacturing as one of its features, it is felt the information requested may be available by your company. It would be appreciated if same could be forwarded to me.

—ROBERT W. AAUMILLER
Beaver, Pa.

Ed—We are sending you lists of forthcoming meetings from recent issues of PRODUCT ENGINEERING and the *American Machinist*. These list meetings covering production and engineering. We suggest you contact *Factory Management & Maintenance*, the McGraw-Hill publication that deals with other manufacturing activities.

ERRATA

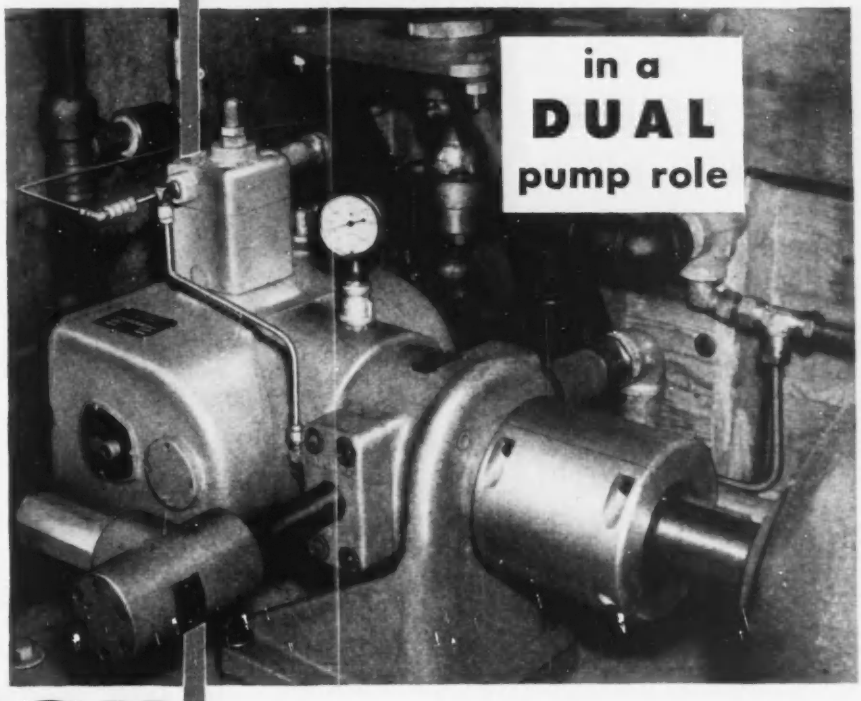
Feb. 1952 Page 242. *Surface Temperatures Accurately Checked.* The Phaostron Company was incorrectly listed as the supplier of this thermometer. Correct supplier is the Pacific-Transducer Co., 11921 West Pico Blvd., Los Angeles 64, California.

Jan., 1952 Page 150. *Diesel Engine Cooled by Forced Air.* Cologne, Rhine is an incorrect address for Kloeckner-Humboldt Deutz A. G. The correct address is Cologne, Germany. Inquiries may be sent in the United States to the Diesel Energy Corp., 47 West St., New York 6, New York.

March, 1952 Page 218. *Nema Frame, Face Mounted, Integral Hp Motors.* Address of this supplier is not 360 N. Michigan Ave., Chicago, Illinois. Correct address is the Hoover Company, 8 So. Michigan Ave., Chicago 3, Ill.

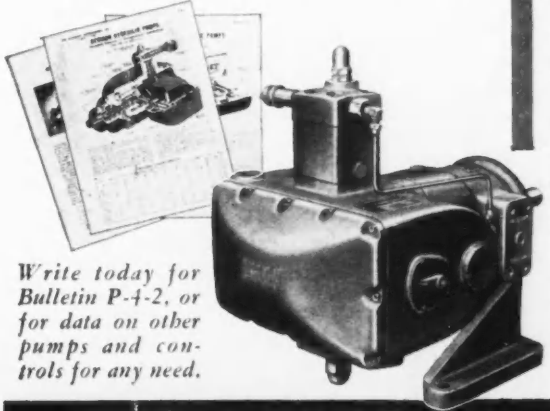
April, 1952 Page 236. *High Voltage Mercury Thyratron Tube.* Correct address of this supplier is Sheldon Electric Company, Inc., 76 Coit St., Irvington, New Jersey.

Rugged Dependability



DENISON

Wherever *high-pressure holding cycles* are required, Denison Compensator Controlled Pumps offer *proved performance* that provides both high volume-low pressure and low volume-high pressure operation in any combination, for any need up to 5000 psi.



Write today for Bulletin P-4-2, or for data on other pumps and controls for any need.

Compensator-Controlled Pumps

Denison Compensator Controlled Pumps play a dual role that cuts costs in circuits designed for intermittent high-pressure operation.

They provide high-volume oil delivery during low-pressure operating periods, then maintain full pressure with *minimum oil delivery* for the hold-down or work period.

Actuated by the system pressure as it reaches maximum, the compensator control automatically changes the volume by regulating the stroke length of the pump pistons.

Compensator controlled pumps save horsepower during dwell periods. Less space is required than in equivalent two-pump circuits. They eliminate many needs for unloader valves, extra piping and double-end-shaft electric motors. They often permit the use of smaller electric motors. Other advantages include increased circuit efficiency, simplified circuit design, and lower maintenance costs.

Rugged, compact construction and dependable axial piston design combine to assure high volumetric and over-all efficiency with long lasting, low maintenance service. Compare the dual efficiency and economy of Denison compensator controlled pumps with the ordinary two-pump set-up. Available in 10, 20, and 35 gpm capacities, for operating pressures up to 5000 psi, they permit unlimited adjustment of control for varying requirements.

DENISON Hydr**OIL**ics

The DENISON Engineering Co.,
1157 Dublin Road, Columbus 16, Ohio

for valving corrosive and "hard-to-handle" fluids . . .

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offers over 20,000 different "custom-made" assemblies on a standardized basis

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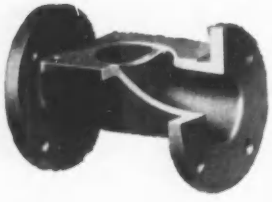

48 standard

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PAG

MISS

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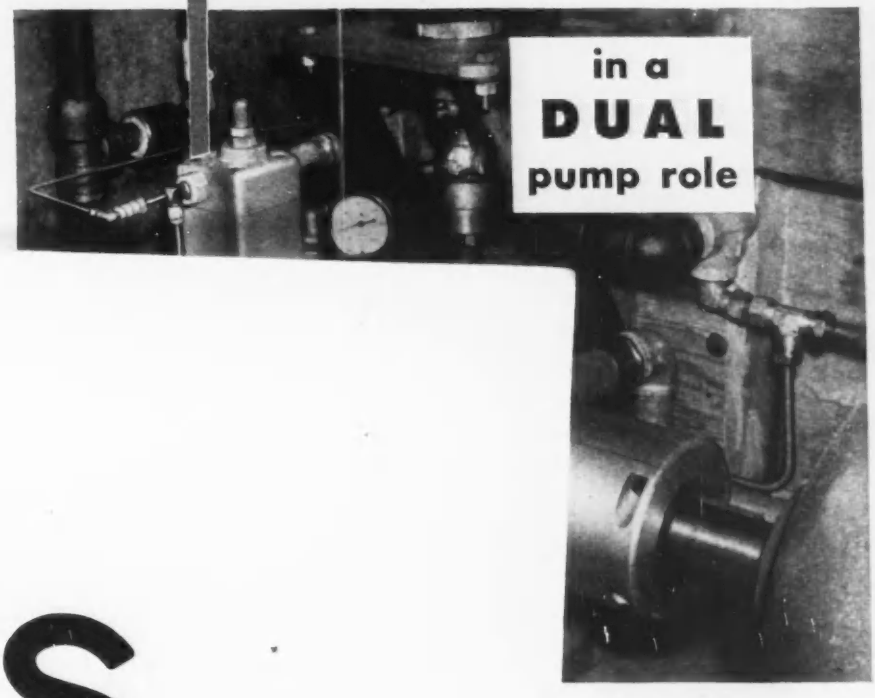

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SSING

rolled Pumps

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for intermittent high-pressure

delivery during low-pressure
in full pressure with *minimum*
or work period.

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needs for unloader valves, extra
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N Engineering Co.,
d, Columbus 16, Ohio

WHAT ARE YOUR INDIVIDUAL NEEDS FOR A

HEAT EXCHANGER COOLER or CHILLER

WHAT SHAPE? WHAT TYPE? WHAT MATERIAL?

for heating or cooling...

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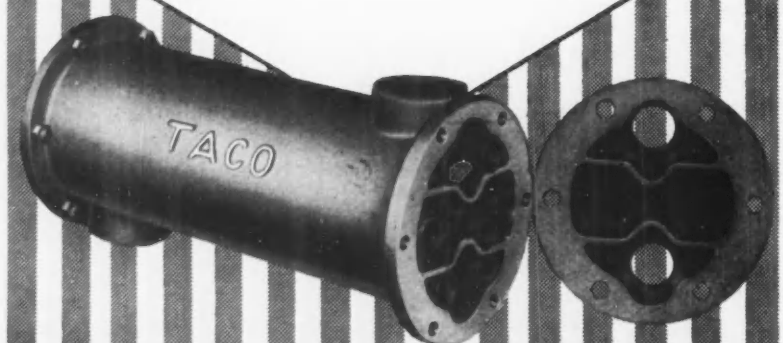

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NEW BOOKS

Sourcebook on Atomic Energy

SAMUEL GLASSTONE, *Consultant, Atomic Energy Commission, 546 pp, 6 x 9 in. Published by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y., $3.40.*

Four years ago, the American Textbook Publishers Institute requested the Atomic Energy Commission to prepare a comprehensive sourcebook on atomic energy for the use of textbook authors and editors. The Commission then obtained the services of Dr. Glasstone to prepare the manuscript.

In his search for background material for this volume, the author studied the work in the Commission's various laboratories and the files of reports on scientific work.

While originally planned for a specific purpose suggested by the Institute, the book is of far broader usefulness in that it provides a source of basic atomic energy information for everyone interested in this field.

Beginning with the earliest theories of the atom and its structure, the author narrates the growth of thought and knowledge in the field. He progresses through the development of the theories of electricity and energy, and the discovery of the phenomena of radioactivity. The reader is carried through the study of isotopes and the development of cyclotrons, betatrons, atomic piles, the new man-created elements, and the release of atomic energy.

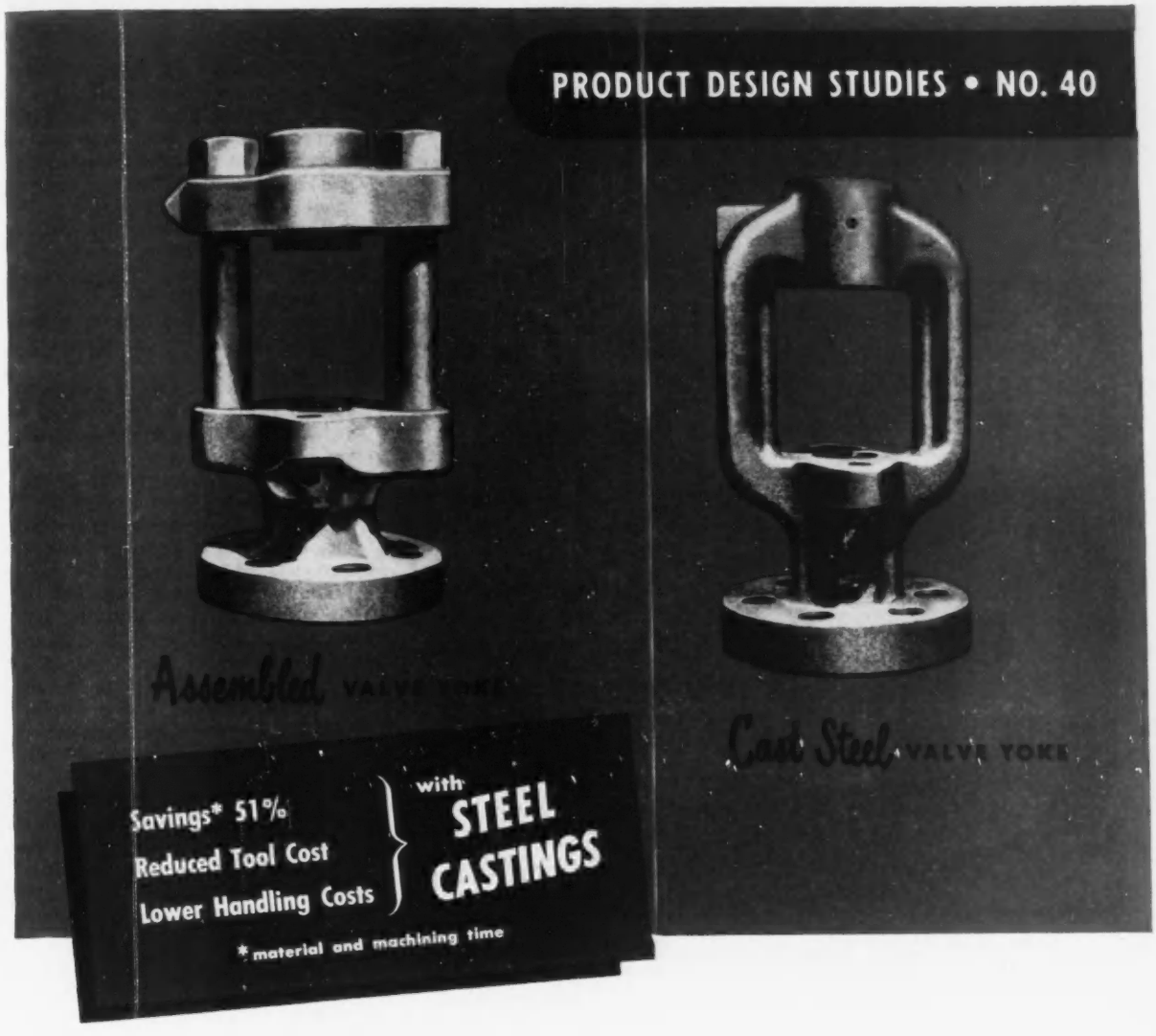
The reader needs only a rudimentary knowledge of science and mathematics to be able to follow this narrative without difficulty.

Researchers should find the chapter on the uses of isotopes to be of practical value. The chapter on radiation protection and health physics should be of interest to all who work with radioactive substances.

Electrical Engineering Sixth Edition

CLARENCE V. CHRISTIE, *Professor of Electrical Engineering, McGill University, 675 pp, 6 x 9 in. Published by McGraw-Hill Book Co., 330 West 42 St., New York 36, N. Y., $7.*

All the material included in the previous edition has been retained in the sixth edition, but a considerable amount of new descriptive material has



Replacement of a six-piece valve yoke assembly of wrought and cast steel with a one-piece steel casting resulted in savings in material and machining time of 51%, or $15.81 per unit.

Other cost advantages of the steel casting over the assembled unit were savings in tool and handling costs.

By using cast steel yokes, the valve manufacturer now stocks one item rather than four. This saves time in purchasing, production, storing, handling and record-keeping.

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Here is another example of the engineering teamwork in design and redesign of parts which is resulting in lower costs and greater serviceability with steel castings.

This service is offered without cost or obligation. It makes available through your foundry engineer the full results of the development and research program carried on by the Steel Founders' Society of America.

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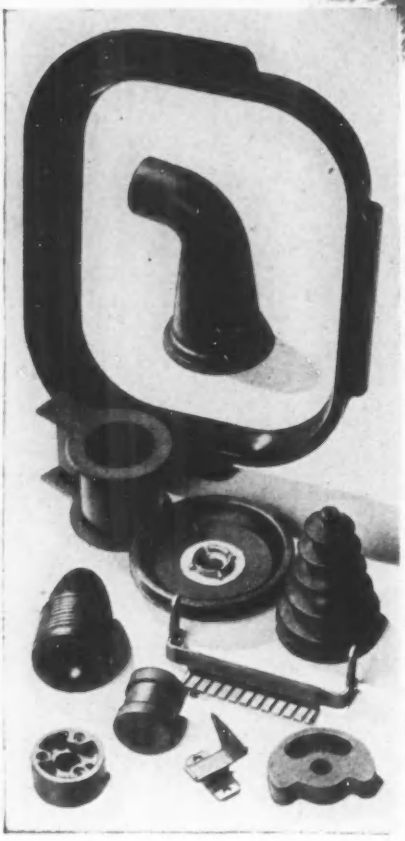

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been added and a number of additional problems have been worked out.

The treatment of alternating-current circuits has been extended to cover some of the more important circuit theorems which should be familiar to all electrical engineers.

There has been a notable increase in the application of direct-current machines and a number of special types have been discussed, the most interesting of which is the armature-reaction-excited machine used in control systems.

The treatment of the polyphase induction motor has been extended to include the main systems of speed control.

The material on mercury-arc rectifier or converter has been brought up to date and has been somewhat extended, but other types of rectifiers have not been included for lack of space.

The study of system faults and system stability has been made of more practical value by the inclusion of numerical examples.

As in the earlier editions, the aim has been to present a logical development of the theory of direct-current and alternating-current circuits and machinery in such a way that the reader will have a suitable background for further study. The emphasis is upon the power field, but the student whose main interest lies in the field of communication engineering will find the material on circuit theory presented in such a way as to prepare him for further study in circuit analysis.

Engineering Materials— Their Mechanical Properties And Applications

JOSEPH MARIN, *Professor of Engineering Mechanics and Research Professor of Engineering Materials; the Pennsylvania State College;* 491 *pp,* 6 x 9 *in. Published by Prentice-Hall, Inc.,* 70 *Fifth Ave., New York* 11, *N. Y.,* $8.70.

The object of this text is to provide the student with sufficient knowledge of the behavior of stressed materials to permit the intelligent selection and use of materials. It attempts to make the subject more analytical, more rigorous, and more directly applicable to design than is done in existing books on the subject.

The mechanical properties of materials, their definition, determination and utilization are covered in Part One. In the general treatment of mechanical properties, static, fatigue, impact, and high and low temperature

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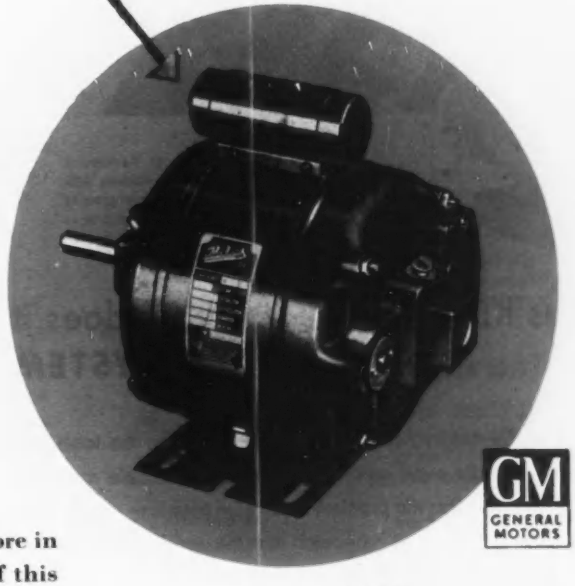

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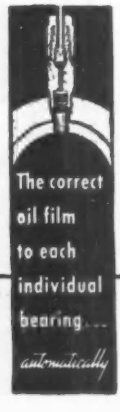
How to **LUBRICATE**
A HORIZONTAL DOVETAIL WAY

View of saddle on Kearney & Trecker CK Milling Machine with table removed to show grooved ways, table nut, and lubricator in lower right corner.

. . . as KEARNEY & TRECKER does it with a BIJUR SYSTEM

To maintain a constant oil film between the table and saddle ways and also between the saddle and knee ways was the problem here. Both problems were solved by building a lubricator into the saddle . . . controlling the oil flow thru a system of meter-units at all four ways and both knee and table nuts . . . spreading the oil evenly over all way surfaces thru "Z" grooves in the saddle ways. This is another example of Bijur "teamwork for bearing protection." For aid in solving your lubrication problems, call in a Bijur engineer.



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loading conditions are considered. The treatment includes the behavior of materials under various types of loads such as tension, compression, bending, and torsion. The utilization of mechanical properties is emphasized and the material presented attempts to give necessary background for subsequent design courses.

Part Two covers a number of important engineering materials. In the discussion of specific materials, emphasis is placed on the mechanical properties and the factors influencing the mechanical properties. A chapter is also included on the structure of materials and the control of their properties.

Part Three presents a discussion of the more important materials testing machines and strain gages that are used for the determination of the mechanical properties of materials.

In a first course on materials, sufficient time is usually not available to cover all the subject matter of this text. For this reason, parts of the book are in small print, and can be omitted without destroying the continuity of the remaining subject matter. Each chapter has problems at the end, with about half the answers supplied.

Selection, Training, and Use of Personnel In Industrial Research

DAVID B. HERTZ, *Editor; and* ALBERT H. RUBENSTEIN, *Assistant Editor.* *274 pp. 5½ x 8½ in. Published by King's Crown Press, 2960 Broadway, New York 27, N. Y.* $4.50.

Proceedings of the second annual conference on Industrial Research, June 1951, sponsored by the Department of Industrial Engineering, Columbia University.

The objective of this conference was to assist research administrators achieve a wider understanding and deeper comprehension of the problems involved in the selection and training of research personnel.

Selection of the best researchers, proper methodological training, and the provision of an atmosphere of intellectual security conducive to high creative effort were the keynotes of the conference discussions. The intensely practical nature of the papers, and the discussions they provoked, should prove valuable in aiding and stimulating those who wish to improve the process of research administration.

The edited papers and discussions that are presented in the volume are:

Research as a Key to World Peace; John R. Dunning.

What Industry Requires of the Re-

JOHNSON BRONZE

SLEEVE BEARING DATA

Bearing TYPES

JOHNSON BRONZE

SLEEVE BEARING DATA

Sheet Metal Bearings-2

Pre-Cast Bronze-on-Steel

WHILE this is a comparatively new type of bearing material, developed and patented by Johnson Bronze, millions of bearings and parts now in constant use provide definite proof of its excellent qualities.

Pre-Cast Bearing BRONZE-ON-STEEL is essentially a thin wall, laminated type of bearing that combines the bearing qualities of a high grade bronze alloy with the strength of steel. We start with a mixture of copper, tin and lead which is universally accepted as the best general purpose bearing bronze available. It combines, in the correct proportion, all the necessary elements to insure the utmost in bearing performance.

By casting this alloy in solid bronze bars we unite the metals chemically and form a definite copper-tin eutectic—with the lead trapped in the interstices. Thus the grain structure of the alloy—and the resulting bearings—is definitely established. Next, we reduce the bronze bar to a fine powder, about the same consistency as talcum. This powdered bronze is then treated in a hydrogen furnace to remove all oxides and then firmly bonded to copper coated strip steel. The process of manufacturing bearings from BRONZE-ON-STEEL, in strip form, is the same as for any other type of sheet metal bearing, being essentially a stamping and forming operation.

Bearings are made from this material in the same manner as bronze sheet metal bushings. The range of wall thickness is between .031" to .110". Lengths of bearings cannot exceed 4½". The smallest I.D. which can be formed is ⅜". Steel thickness for .052" wall bushings is .036"; for .070" wall it is .050" thick.

BRONZE-ON-STEEL is assembled by the same methods ordinarily used for bronze metal. It can be burnished with ordinary tools. It is also possible to bore and ream this material, but special carbide tipped tools are necessary. Diamond boring is sometimes recommended as a finishing operation.

Chemical and Physical Properties of Bronze-on-Steel

CHEMICAL ANALYSIS	Plain Bronze	Graphited Bronze
Copper	Balance	Balance
Tin	8-11	8-11
Lead	8-11	8-11
Graphite	none	1.0 max.

PHYSICAL PROPERTIES

	(1) Rockwell Hardness E Scale	(2) Wear Rate	(3) Coefficient of Friction	(4) Resistance to Pounding	(5) Resistance to Pounding
Plain Bronze	55 min.	0.09	0.14	64	447
Graphited	55 min.	0.02	0.13	57	255

1. Rockwell Hardness, E scale 100 Kg. Load—⅛" ball.
2. Wear Rate Loss of weight in grams—1 hour run, 1" I.D. bushing at 400 R.P.M.—.005" clearance—25 lb. per sq. in. pressure—no lubrication.
3. Coefficient of Friction—as determined on J. B. Machine. No lubrication.
4. Resistance to pounding—number of blows of 60 lb. hammer falling 2" to deform specimen .001"—1" x 1" x 1/16" specimen.
5. Same as (4) with deformation going to .005".

Specifications

	Standard Wall Thickness	For Shaft Diameters
1.	.032—.035	From 5/16" to 1½" Shaft
2.	.042—.045	From ⅜" to 1¾" Shaft
3.	.062—.065	From ⅝" to 2¾" Shaft
4.	.092—.095	Over 1¼" Shaft

In order to obtain the best results from Pre-Cast Bearing BRONZE-ON-STEEL bushings and bearings, it is advisable to include the following information in your specifications:

1. SIZE of hole bushing is to be pressed into—rather than O.D. of bushings.
2. SIZE I.D. required after pressing into place. Manufacturers standard tolerance .002.
3. TYPE of body or housing bushing is pressed into.
4. SPECIAL FEATURES of bushing should be fully explained including their purpose.

Thrust Washers

While BRONZE-ON-STEEL was developed primarily for Bushings and Bearings it also fills many other important industrial uses. It is ideal for applications requiring a flat bearing surface such as plates, washers, etc.

Some manufacturers prefer to purchase BRONZE-ON-STEEL in rolls and do their own stamping and forming. For such cases we can furnish it in rolls up to 400 feet in length. The maximum width of the strip cannot exceed 6½ inches.

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This bearing data sheet is but one of a series. You can get the complete set by writing to—

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search Worker; Elmer W. Engstrom.

The Creative Mentality and Research Problems; David B. Hertz.

Selection Techniques for Research Workers; John C. Flanagan.

Training of Young Researchers; H. A. Leedy.

Methodology and Mathematical Statistics and Their Application in Research; Russell L. Ackoff.

Industrial Research Workers and Defense; Phillip N. Powers.

Research and National Manpower Policy; Ralph M. Hogan.

Preliminary Report on University Research Potential; John I. Mattill.

The University's Role in Training Research Workers; Harold K. Work.

Coordination of Research and Development Work; John A. Leermakers.

External Communication of Research Results; H. B. McClure.

What Makes a Good Research Man?; Sebastian B. Littauer.

In addition to these papers, about one-fourth of the book contains relevant and abridged material from small group sessions that were held during the conference for discussions of individual problems.

Basic Engineering Thermodynamics

VINCENT W. YOUNG, *consultant in thermodynamics, 558 pp, 6 x 9 in. Published by the McGraw-Hill Book Co., Inc., 330 West 42 St., New York 36, N. Y., $6.50.*

The clear and logical treatment of the overall coverage of thermodynamics as presented by the author reflects his long experience in teaching. He anticipates and stresses those portions of the subject that frequently prove to be troublesome to students.

In preparing this text, five objectives have been kept in mind: Material is selected to avoid an uneconomical use of time; material is organized to result in a continuous development of the main theme; balance and consistency; treatment is sufficiently rigorous to prove the soundness of the argument; and readability to promote continuity of thought.

While the treatment is essentially conventional, certain features are new. These include the early identification of the reversible process as a maximum-work operation, and the use of the maximum-work concept in the development of thermodynamic theory throughout the book. Also, in the chapter on heat transfer, the subject of convective flow is introduced in a new way.

Heat transfer and those applications

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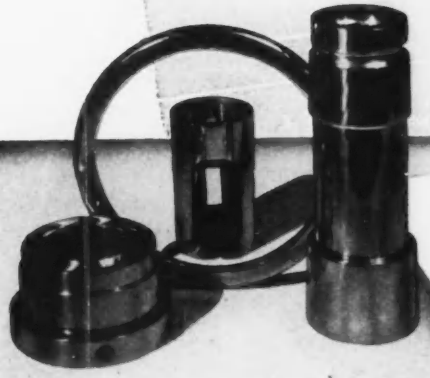
All the facilities, equipment and resources of the Bunting Brass & Bronze Company are created to serve the buyer as well as to manufacture a product. Ask any Bunting customer.



The sleeve bearing is not complex in structure; it conforms readily to design requirements; it is easily installed. Cast Bearing Bronze is the most adaptable of all sleeve bearing materials; it possesses excellent anti-friction properties. With proper film lubrication, its coefficient of friction is as low as can be obtained with any other bearing type. A successful Bunting Bronze bearing installation is readily attainable. We ask the opportunity to work with you, and to quote on your requirements.

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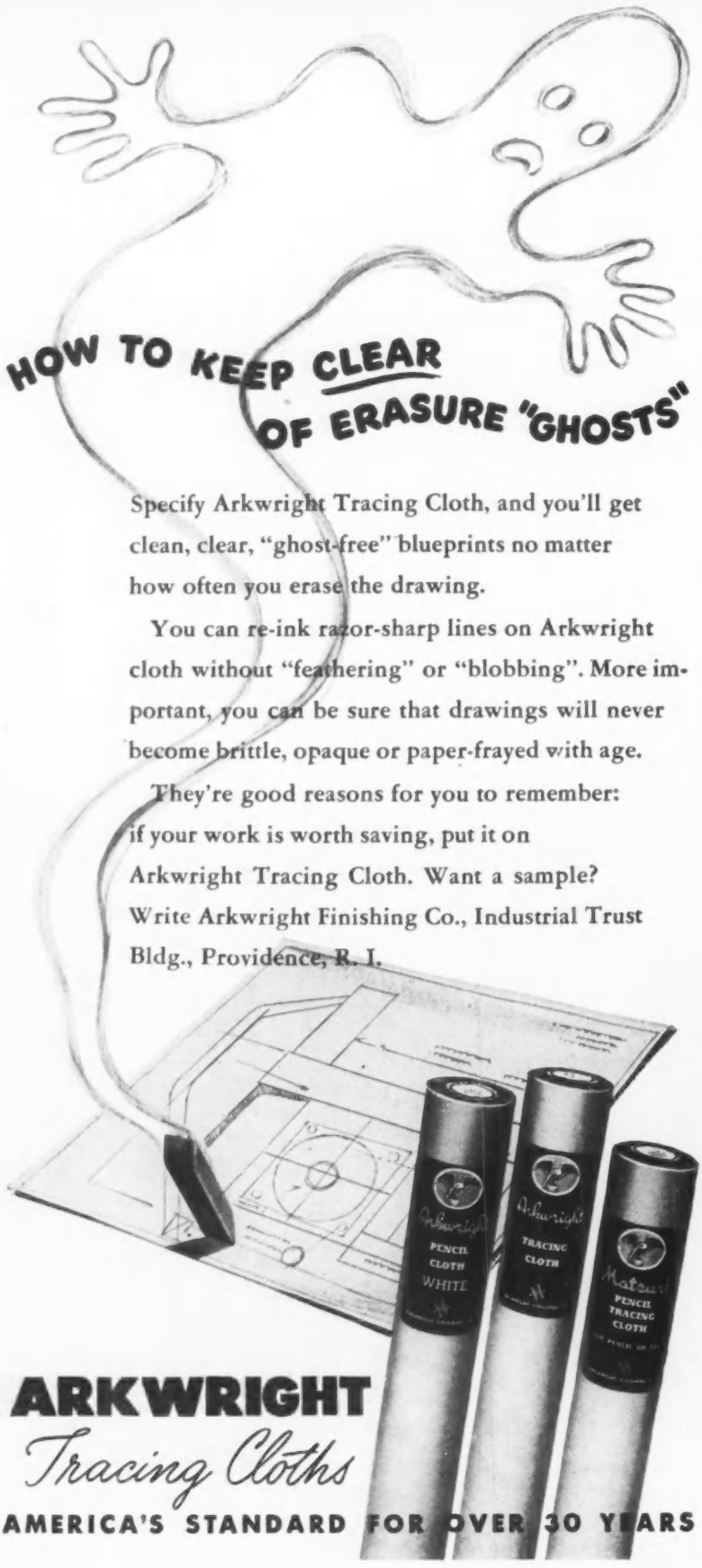
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of thermodynamics to chemistry that are of interest to the engineers are also discussed.

Although the development of the overall subject is basically theoretical, it is closely associated with practical considerations by a discussion that emphasizes the differences between the real and the ideal operations, and by means of numerous examples of a practical character.

Machinery and Equipment for Rubber and Plastics *Volume I*—Primary Machinery and Equipment

Compiled by ROBERT G. SEAMAN, *Editor, and* ARTHUR M. MERRIAL, *Associate Editor* 6 x 9 *in,* 804 *pp. Published by India Rubber World,* 386 *Fourth Ave., New York* 16, *N. Y. In U. S. A.,* $15; *elsewhere,* $16.

This book has been compiled for those men of the rubber and the plastics industries who are responsible in one way or another for the processing of the various raw materials used by these industries into many thousands of finished products daily. Basically, the book is an attempt to provide the rubber and the plastics industries with classified information for their manufacturing operations on what machines are available for use, how they work in the manufacture of the finished products, and where they may be obtained. As such, we believe it will fill a need.

To be published in two volumes, of which this volume is the first, this book was prepared mostly from information made available to India *Rubber World* by more than 750 suppliers of machinery and equipment. More than 1,200 supplier companies were contacted. While certain suppliers and their products are not included, this omission was not due to lack of effort on the part of the editors.

A special feature of the book is the series of general summary articles on the several types of machinery covered as well as procedures for the manufacture of several major types of rubber products and plastics films and sheeting, which precede the classified information of each chapter. These articles, each written by a specialist in the field, have considerable significance, particularly those on rubber goods manufacture, where there is a dearth of such information.

Not since 1915, when "Rubber Machinery" was published by the late Henry C. Pearon, former editor of India *Rubber World,* has there been

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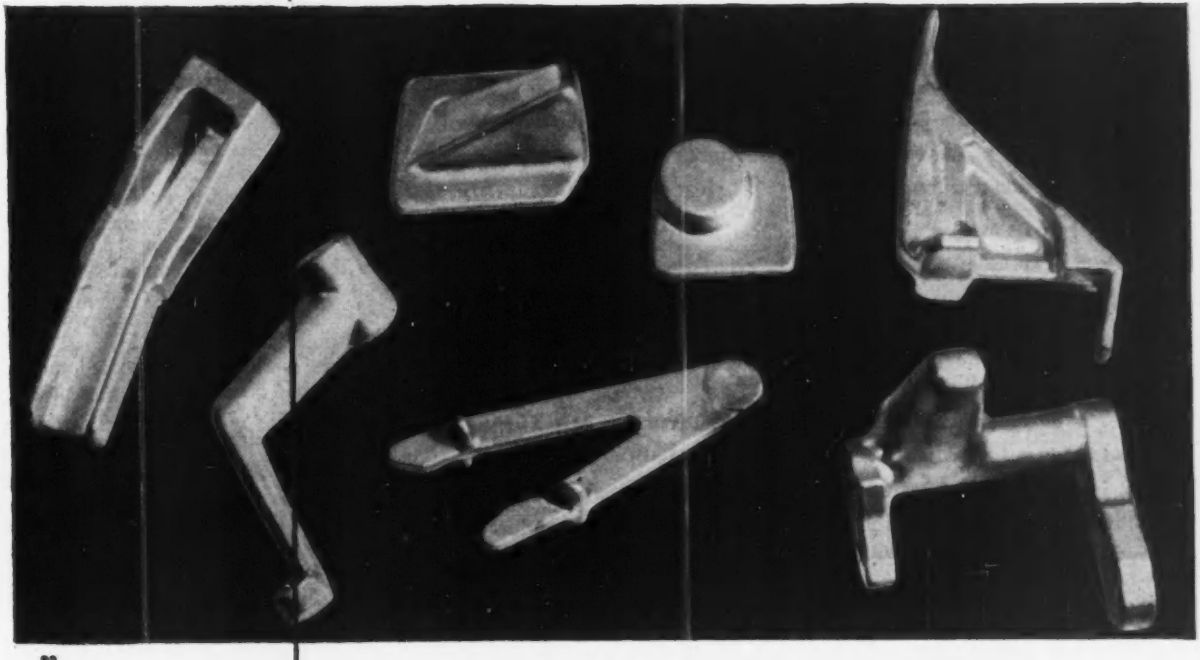

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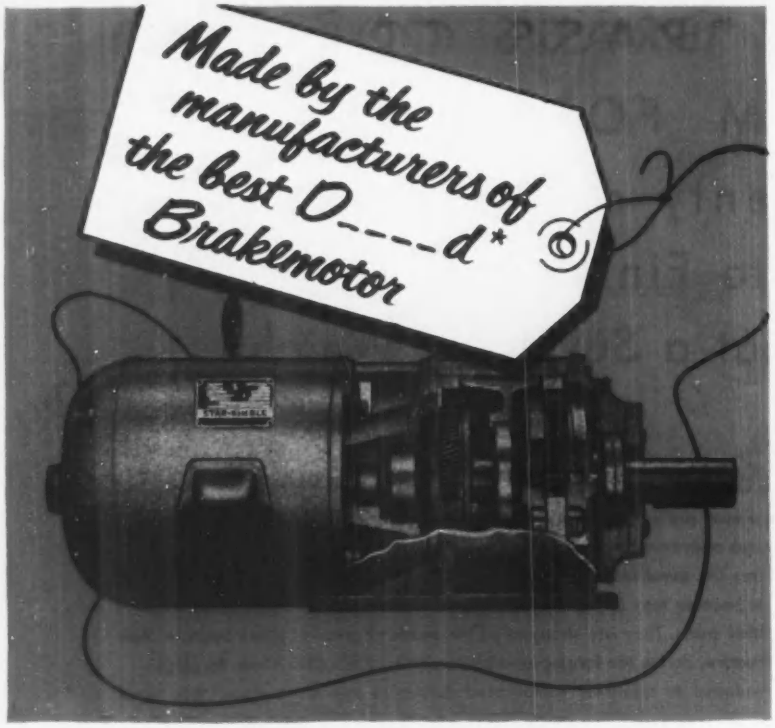

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THE planetary gear speed-reducing system used and proved for a quarter of a century in Star-Kimble Gearmotors distributes the bearing load uniformly and reduces the risk of wear.

Helical gears of the planetary system are precision-shaved in Star-Kimble's own plants for the continuous tooth contact that assures quiet operation and long life.

Moving parts within the sturdy reducer housing maintain a constant fine spray of lubricant from an oil reservoir to the bearings and gears. Oil seals prevent leakage.

Tapered roller bearings on output shaft eliminate end play—allow Gearmotor to be mounted in any position.

Most important advantage of all is the fact that every Star-Kimble Gearmotor is an integrally designed, integrally built unit. All parts are Star-Kimble engineered to work smoothly and efficiently together—all motors, gears and other major components are produced by Star-Kimble.

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available a book of this nature. In accordance with present-day trends the scope of the new book has been expanded to cover machines and methods used for the processing of many plastics materials.

An Editorial Advisory Board, composed of approximately equal numbers of representatives of the machinery supplier and user companies, was established at the outset to guide the editors on matters of scope, modern developments and usage, and the best sources of information on the many classifications of machines and processes to be covered.

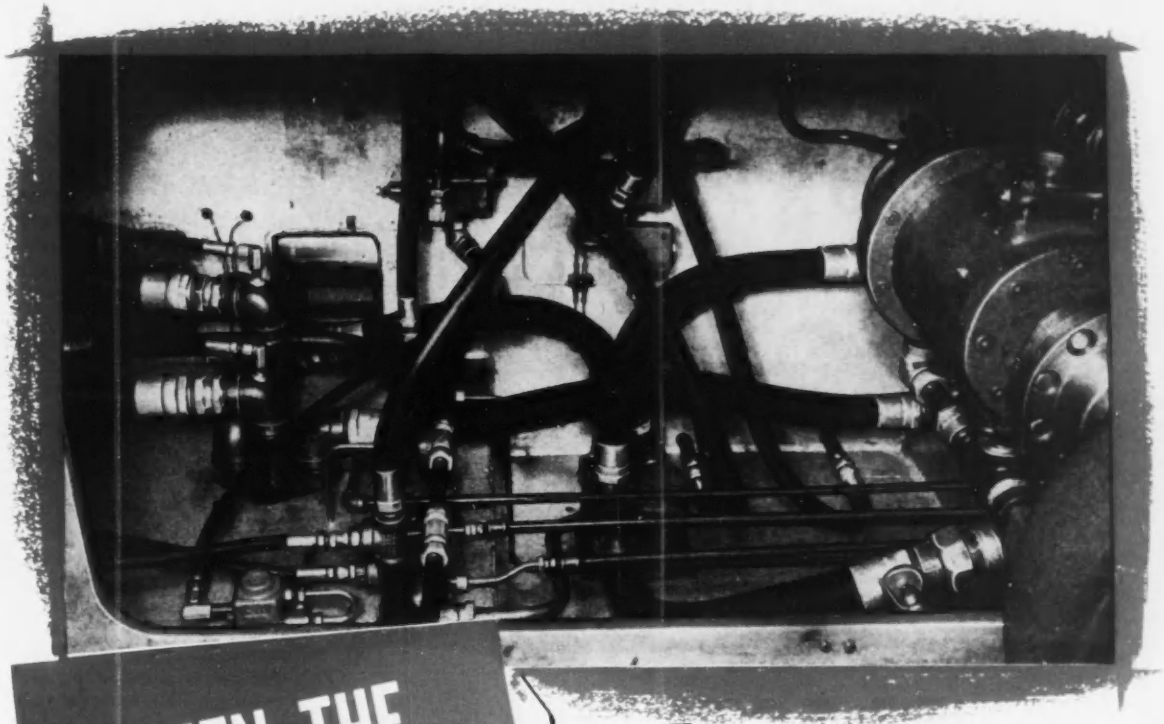
This first volume is devoted to Primary Machinery and Equipment: Mills, mixers, calenders, extruders, presses, etc., and the special machines and equipment used for the manufacture of tires and tubes, hose and belting, wire and cable, latex goods, and plastics film and sheeting. The second volume will cover Supplementary Machinery and Equipment, i.e., materials handling, size reduction and separation, cutting and trimming, industrial control instruments, laboratory equipment, valves and piping, power transmission, air handling and lubrication.

Machines and equipment described in each chapter from information provided by the supplier companies are the editor's interpretation of the statements in the companies' literature regarding the various types and models. Clarification and revision of some of these statements were requested in a number of instances, but obviously, because of the tremendous number of items involved, most of the information was recorded essentially as received. Responsibility, therefore, for the majority of statements must rest with the supplier companies. Tables of specifications and other engineering and operating data are used wherever possible. Not all models of all companies' machines are illustrated, but an effort has been made to present one illustration for each different class of machine that is in use wherever possible and practicable.

Practical Radiography For Industry

H. R. CLAUSER, *Managing Editor, "Materials and Methods,"* 301 *pp*, 6 x 9 *in. Published by Rheinhold Publishing Corp.*, 330 *West* 42 *St., New York* 36, *N. Y.*, $7.50.

Unique in its practical, how-to-do-it approach, this useful volume provides radiographers, inspectors, metallurgists, engineers, technicians—in fact, anyone concerned with the non-de-



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ANCHOR Hose and Ductile Sleeve Couplings handle it

easily, efficiently, safely

EXTRA safety, unusual dependability — that's what the manufacturer of this 25-ton 66" Double Ram wanted. And that's why he specified Anchor Ductile Sleeve Couplings and Hose. Like many other manufacturers of machinery using hydraulic systems, he knows Anchor's exclusive patented grip makes the coupling virtually a part of the steel reinforcing wire of the hose — eliminates leaks and troublesome blow-offs.

HERE ARE ADDITIONAL REASONS why Anchor two-wire braid high-pressure hose assemblies were selected for this tough job:

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Anchor also makes a complete line of adapter unions and related fittings for practically every pressure or suction job. Take advantage of the many outstanding features in the most complete line of hose assemblies and fittings available. Benefit by the plus margin of safety and the greater dependability offered by Anchor.

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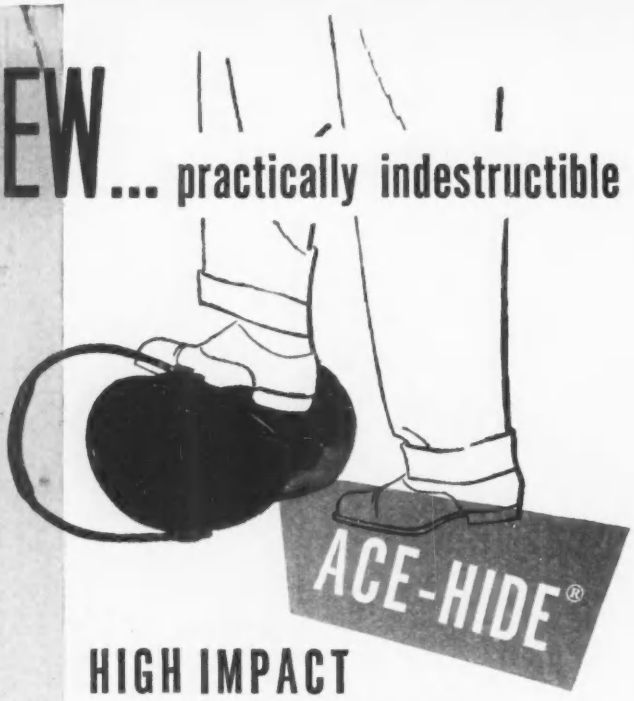

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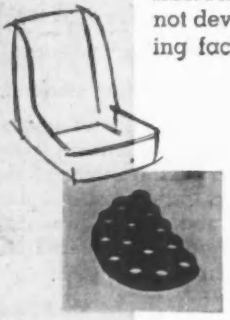

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Separate chapters are devoted to radiography with radium and Cobalt 60, fluoroscopy and miscellaneous applications including such recent advances as radiation detectors, micro-radiography and thickness-gaging methods. Latest information is also presented on high voltage radiographic techniques using 1, 2, 10 and 22-million volt X-ray equipment.

This volume is directed primarily to those who actually perform radiographic inspections and to those who read or interpret radiographs and evaluate their findings. However, equipment and fundamental principles are treated in a concise, relatively non-technical manner thoroughly understandable even to those with little or no training in physics or mathematics.

Sampling Inspection By Variables

ALBERT H. BOWKER, *Assoc. Prof. of Statistics, Stanford University,* HENRY P. GOODE, *Assoc. Prof. of Mech. Eng., Stanford University.* 216 *pp.* 6 x 9 *in. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York 36, N. Y.* $5.

A set of plans is presented for sampling inspection where item quality is expressed on a variables basis; that is, the item characteristic being inspected is measured and the reading recorded, as opposed to inspection on an attribute basis, which simply classifies an item as defective or non-defective.

For many applications, plans based on variables are superior to those based on attributes, particularly as a means of reducing the overall sampling inspection costs. The plans are presented as part of a standard variables sampling procedure that can be applied to many products but can also be used as a catalog of ideas by those who construct tailor-made procedures.

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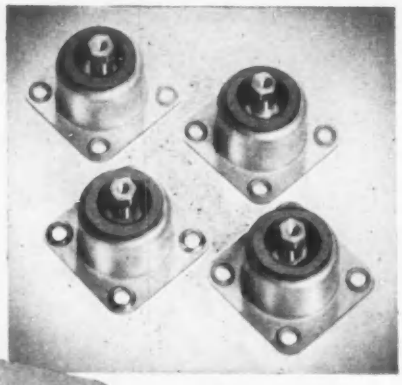
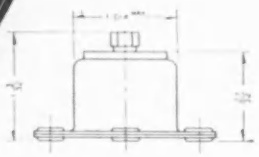


Photo courtesy Vapor Heating Corp.



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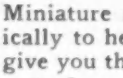
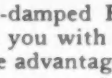


TYPE 6465



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variables plans are presented. To assist in a more complete understanding of the plans and their use, elementary principles of sampling inspection are discussed, particularly when inspection is by variables. Illustrative examples of uses are included. Two chapters are aimed at readers with a more theoretical interest; Chapter 10 discusses the disposition of some of the problems that arose during the preparation of the plans, and Chapter 11 gives the mathematical theory behind the plans. The appendix describes practical computing techniques and graphical methods of applying the acceptance criteria which minimize the routine calculations required. Although many items common to both attribute and variables plans, such as the procedure for selecting a sample are not treated in detail, the discussion is intended to be complete enough to enable installations to be made without reference to other plans or material.

Mechanics of Vibration

HOLGER M. HANSEN *and* PAUL F. CHENEA, *Prof. and Assoc. Prof. respectively, of Engineering Mechanics, University of Michigan.* 417 *pp.* 6 x 9 *in. Published by John Wiley & Sons, Inc.*, 440 *W. 4th Ave., New York* 16, *N. Y.* $8.

Divided into three parts, this text deals first with steady state vibration of systems of one degree of freedom. Since these systems are fundamentally significant in most forms of vibration, a considerable amount of space is devoted to them. Both free and forced vibrations are included. In the latter case, separate chapters are devoted to conditions with and without damping.

The second part of the book extends the theory to systems of several degrees of freedom. The theory is discussed from the classical standpoint although emphasis is placed on the extremely useful "mobility" concept.

The third section consists of an introduction to special topics, which are an essential part in a more general and refined analysis of vibration problems. These topics include non-linear systems, systems with distributed physical characteristics, and systems subjected to transient motions. While a thorough discussion of these topics is beyond the scope of this book, it is believed that an introduction to these subjects is desirable to link the idealized and more exact theories.

In general, these are the seven features of this book:

1. Several methods of presenting the fundamental concepts are included

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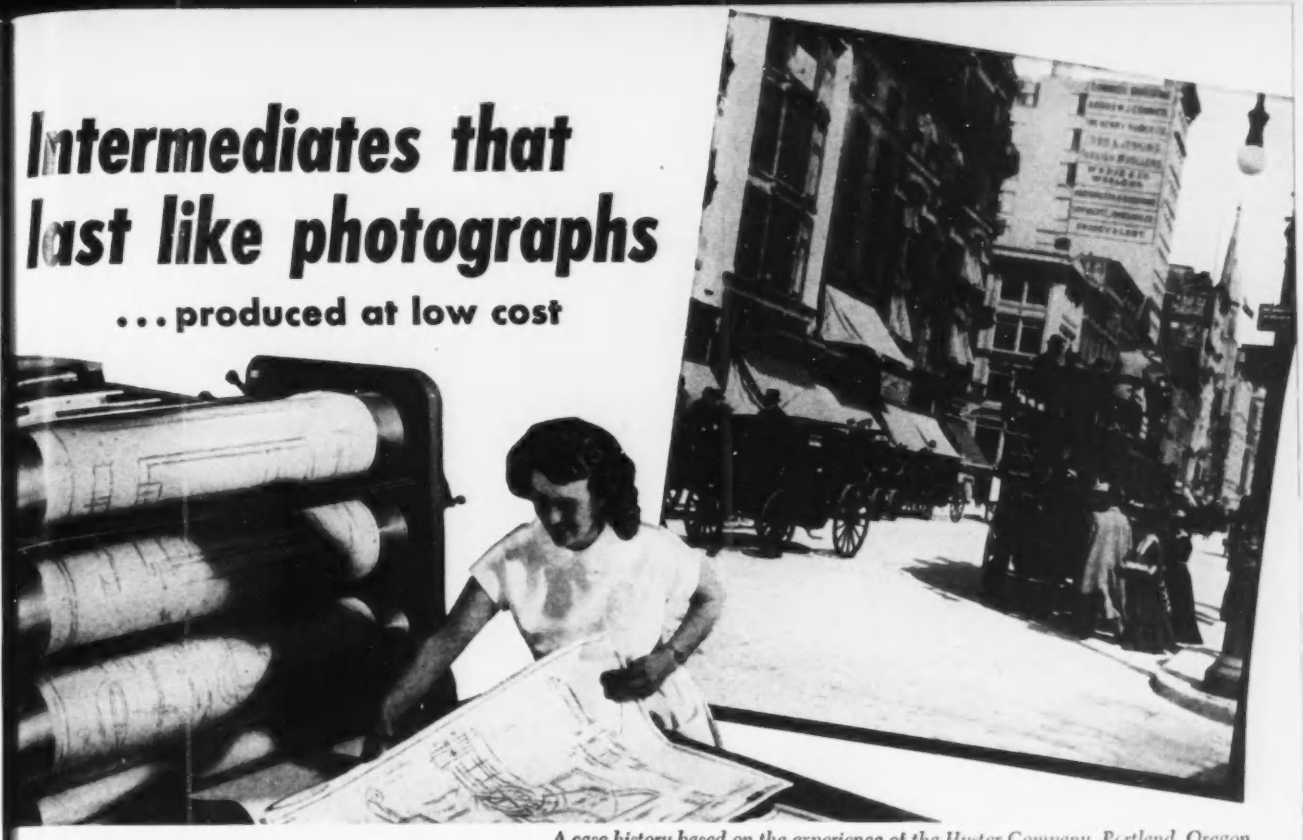

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for clarity and better understanding.

2. The concept of relaxation frequency and its physical meaning is introduced—and this convenient concept is used throughout.

3. The use of equivalent springs, dampers, and masses is stressed in the analysis of complex problems.

4. Energy methods in general are discussed and are used extensively in certain applications.

5. The mobility concept is treated extensively. The use of velocity as a parameter, preferably when dealing with problems of sound transmission, fluid flow and electric currents, is replaced by a displacement parameter, which has more direct significance in mechanical vibrations.

6. The solution of the frequency equation is given considerable attention and alternative methods of calculating frequencies are presented.

7. The vibration system with a non-linear restoring force is discussed and a general method of obtaining the first non-linear approximation is presented in some detail in the book.

Elements of Ceramics

F. H. NORTON, *professor of ceramics, Massachusetts Institute of Technology, 250 pp, 7½ x 9½ in. Published by Addison-Wesley Press, Inc., Kendall Square, Cambridge 42, Mass., $6.50.*

This book covers the principles underlying the various processes used in the ceramic field. The emphasis is placed on unit processes, rather than of discussion of ceramic products. The material presented has been selected to serve as a reference for research workers in this field, to be of assistance to advanced ceramic craftsmen, and also to be used as a textbook. Throughout the book, an effort has been made to carry visual education as far as practicable by the use of carefully prepared illustrations.

An outline of the contents of the book will indicate the scope of the subject matter covered. Crystal chemistry and how it applies to the silicates and the clay minerals. Origin and occurrence of clays. Properties of clays Silica and feldspar. Magnesite, lime, dolomite, and chromite. Mining and treatment of the raw materials. Flow properties of ceramic pastes and slips. Properties of plastic masses. Methods of forming ceramic ware. Drying of ceramic ware. Thermochemical reactions. Types of ceramic bodies. Thermochemical changes in clays and bodies. Construction and operation of kilns. Properties of matter in the glassy state. Composition of glasses

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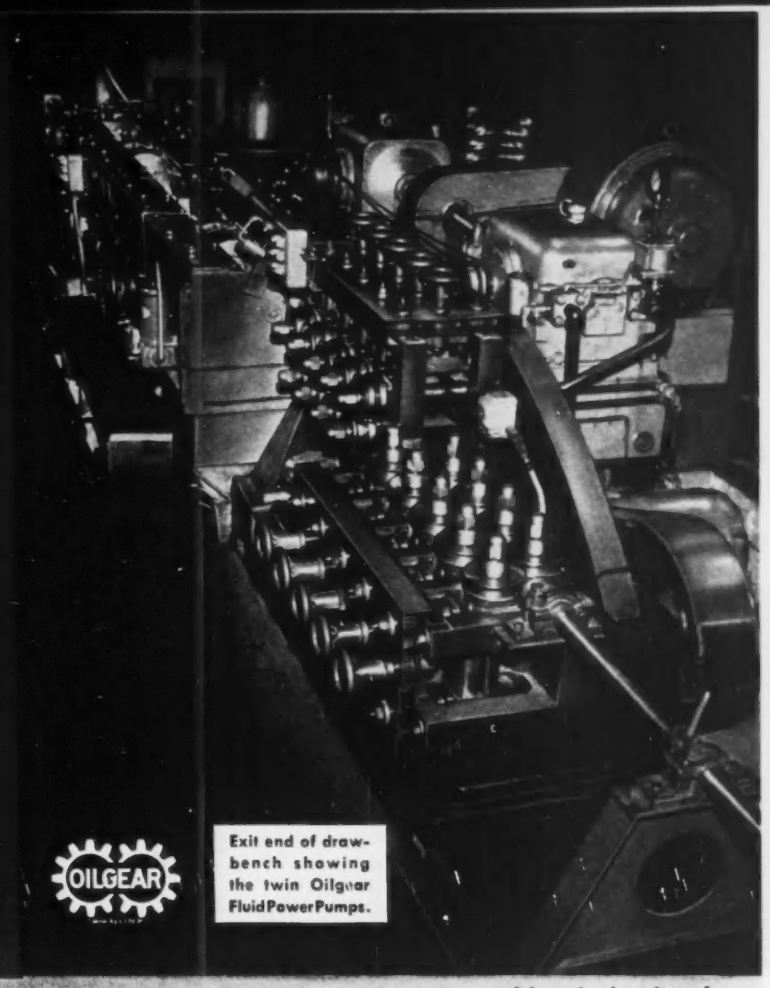
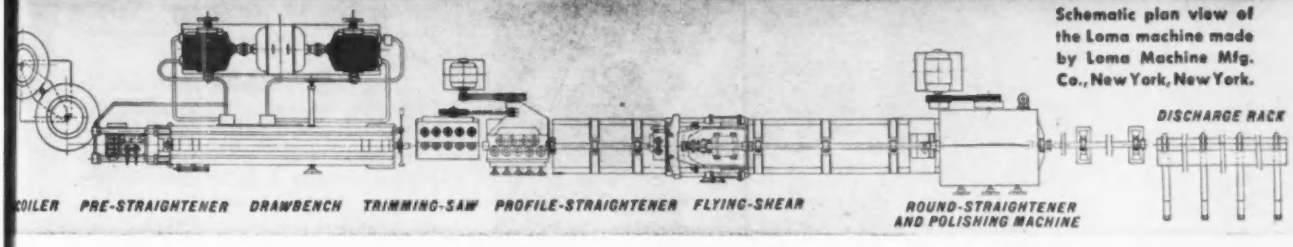


Exit end of drawbench showing the twin Oilgear FluidPowerPumps.



Schematic plan view of the Loma machine made by Loma Machine Mfg. Co., New York, New York.

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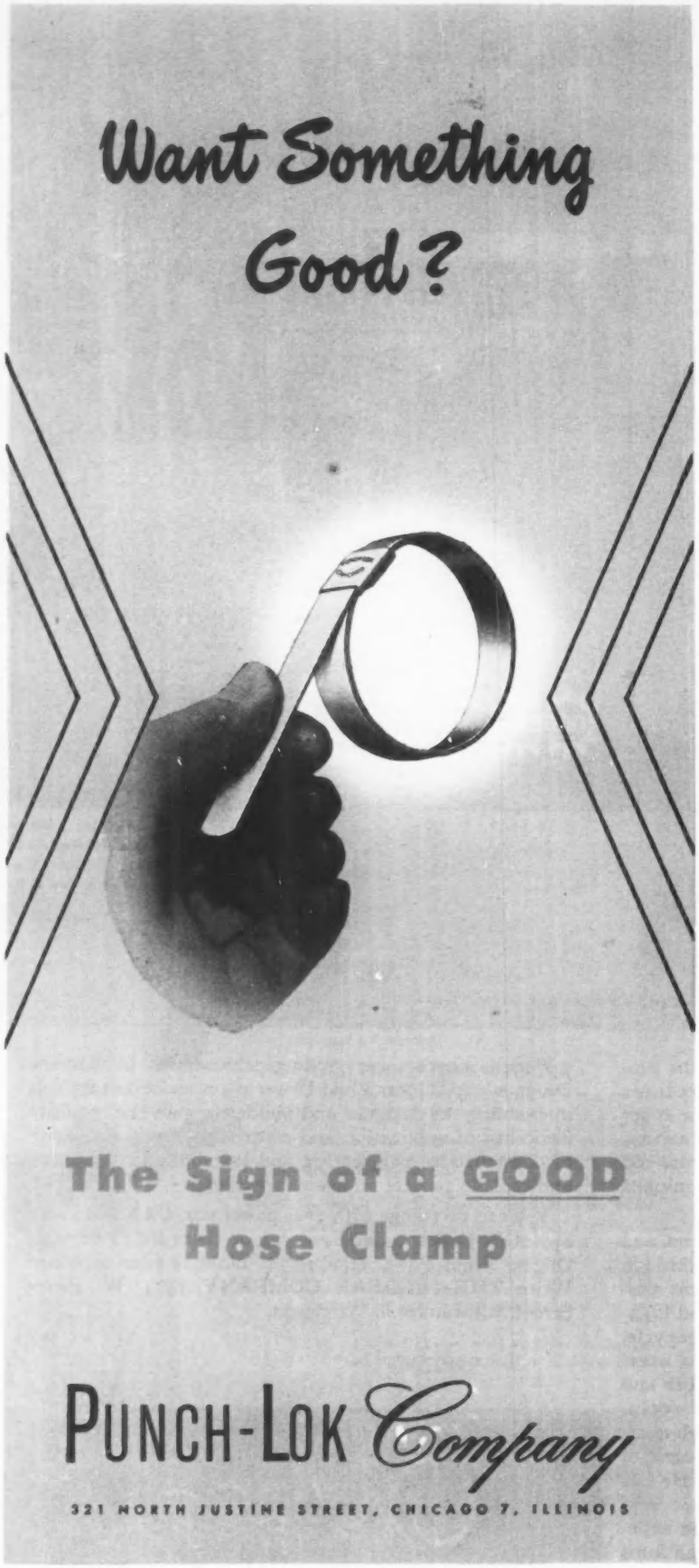

and manufacturing techniques. Composition and application of glazes. Enamels on metal. Color formation in glasses and glazes. Ceramic stains and colors. Processes used for decorating ceramic ware. Composition of cements and plasters.

Powder Metallurgy

160 pp, 6¼ x 9¾ in. Volume 9 of the Selected Government Research Reports, published for the Technical Information and Documents Unit of the Department of Scientific and Industrial Research by His Majesty's Stationary Office. $2.52.

The reports collected in this volume have been selected from research work carried out under the direction of the British Ministries of Supply and Aircraft Production, now combined as the Ministry of Supply. There are ten reports in all. These are: the surface energies of Metals and Alloys; Examination of Sintered Metal Components; Properties of Engineering Iron Powders; Production of Iron Powder by Electrodeposition; German Sintered Iron Bearings; Sintered Iron Driving Bands for 20mm ammunition; Sintered iron—copper compacts; aluminum alloy made by powder metallurgy; German developments in non-carbide powder metallurgy; Tensile strength of titanium at various temperatures.

These reports include up-to-date information on each of the aforementioned subjects. This volume is well illustrated with photos, photomicrograph charts and sketches. It presents complete theoretical and practical information relating to the powder metallurgy science and techniques.

Manufacturing Processes

Third Edition, MYRON L. BEGEMAN, *Professor of Mechanical Engineering, The University of Texas. 6 x 9 in., 608 pages. Published by John Wiley & Sons, Inc., New York, N. Y.* $6.

By combining into one volume the subjects usually taken up in metal processing or shop laboratory courses, the need for several texts is eliminated. Approximately fifty per cent of the book is devoted to the subjects of foundry practice, pattern work, plastic molding, powder metallurgy, hot and cold working of metals, heat treatment and welding. The latter half of the book is given over to measuring instruments, cutting tools, machines and their accessories. In all cases the information is fundamental in character,

describing the machine or process as well as discussing its range of application and limitations. In preparing this material, an attempt has been made to present it in a logical sequence so as to give the reader a comprehensive picture of present-day manufacturing processes. The subject matter is condensed as much as possible, omitting those details that can easily be covered by lecture. The purpose of the text continues to be the training of engineers in technical fundamentals of important manufacturing processes, engineering materials, and in the modern machine tools necessary for processing these materials. It should also be found useful as reference reading for graduate engineers, especially those engaged in production work, designing, and tool engineering.

New chapters in this edition are Cold Forming of Metals—Miscellaneous Processes, and Cold Forming of Metals—Press Work. In addition, the chapters, Special Casting Methods, Plastic Molding, and Welding and Allied Processes have been rewritten with much new material added. All other chapters have been carefully revised with particular empasis on recent developments of the various machines and processes and the tools they use. Special attention has been given to the illustrations, most of which are new.

Industrial Process Control By Statistical Methods

JOHN D. HEIDE, *Industrial-Statistical Analyst, United States Rubber Company,* 297 *pp,* 6 x 9 *in. Published by McGraw-Hill Book Co.,* 330 *W.* 42 *St., New York* 36, *N. Y.,* $6.

In this practical manual, the industrial reader will find how to use statistics to control the quality of industrial products during the manufacturing process.

Here is adequate training both in the statistical methods required and in the practical and technical problems of applying them to factory processes. Keeping mathematics on as nontechnical a level as possible, the book tells, in step-by-step detail: (1) how to install a program of statistical quality control in the factory; (2) how to operate and administer an established program.

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(b) How to construct frequency histograms and curves.
(c) How to estimate factory process

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distributions and their relation to process control.

(d) How to design and construct control charts, with an explanation of their relation to frequency distribution.

(e) How to tell how reliable test results are.

Because this book deals only with the statistical control of the industrial process, it is able to give a thorough and complete coverage of this fundamental field of manufacturing.

Proceedings of the National Electronics Conference, 1951

Volume 7, 607 pp, 6 x 9 in. Published by National Electronics Conference, 852 East 83 St., Chicago 19, Ill., Cloth Bound, $5.

Here printed together in standard book form are the papers presented at the most recent National Electronics Conference. This was held in Chicago, beginning on October 22 of 1951. The Conference is sponsored by the AIEE, Illinois Institute of Technology, IRE, Northwestern University, University of Illinois, with the Society of Motion Picture and Television Engineers and the University of Wisconsin participating.

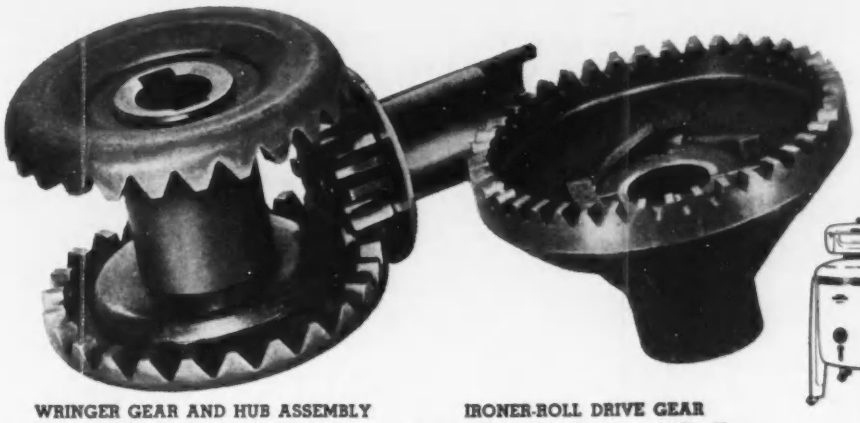
There were a total of 19 separate sessions at the Conference. Of particular interest were the following: Servo Theory and Distance Measurement; Application of Magnetic Amplifier; Industrial Inspection and Measurement; Industrial Applications; a second session on Magnetic Amplifiers; and, Components, Measurement and Assembly. The several papers given at each of these sessions cover most of the latest developments in the fields covered during the meeting.

College Physics

ROBERT L. WEBER, MARSH W. WHITE, *and* KENNETH V. MANNING; *The Pennsylvania State College, 820 pp, 6 x 9 in., Published by the McGraw-Hill Book Co., 330 West 42 St., New York 36, N. Y.,* $6.50.

This second edition follows the general plan of the first edition. The authors present the basic ideas of physics at the college level. The subject matter is presented in a method that develops ability to apply basic physical principles with confidence and facility in the solution of physical problems.

Throughout the text, the vitality of physics is emphasized, especially in the chapters on atomic and nuclear



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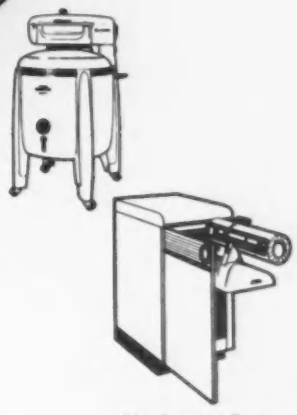

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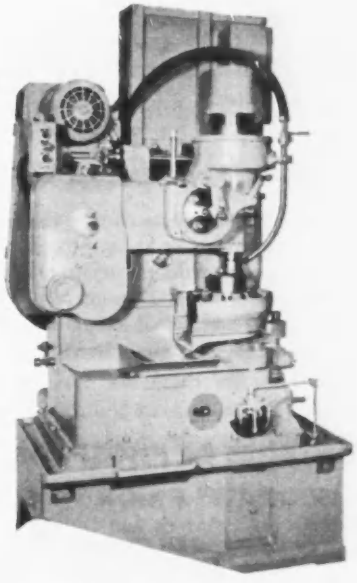

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AMBLER PENNA.

Technical Service Data Sheet
Subject: IMPROVED DRAWING AND COLD FORMING WITH GRANODRAW

INTRODUCTION:

When steel is phosphate coated with "Granodraw" prior to working it, drawing, extrusion, and other cold forming operations are greatly improved. In fact, the protective phosphate coating makes the cold extrusion of steel possible.

Getting cold steel to flow depends on the unique properties of this coating. Its non-metallic phosphate crystals are physically and chemically adapted to acquire a strongly adsorbed lubricant. The combination of adherent phosphate coating and adsorbed lubricating film possesses a low coefficient of friction while maintaining its integrity under extremely high deforming pressures.

The drawing of wire and many other cold forming operations — including the cold extrusion of steel — are greatly facilitated by the application of a "Granodraw" phosphate coating and a suitable lubricant prior to working.

"GRANODRAW" DATA

"Granodraw" zinc phosphate coating chemical is applied to pickled surfaces in an immersion or spray process. When used with a suitable lubricant, the coating reduces friction under conditions of low, medium, or high deforming forces encountered in such typical operations as: cold extrusion of steel; cold shaping; deep drawing (tubs, cartridge cases, shells, etc.); stamping; drawing of wire and tubing; ironing; necking; nosing; and upsetting.

ADVANTAGES OF PHOSPHATE COATING WITH "GRANODRAW" PRIOR TO COLD FORMING STEEL

The following are among the advantages indicated for phosphate coating with "Granodraw" prior to cold forming steel:

Drawing of wire, bars, tubing, etc. — Improved lubrication; improved surface; less scratching; reduced pull; greater percent reduction per pass; reduced die wear; longer die life; lower die maintenance and cost; reduction in corrosion.

Drawing of stampings, shells, shell cases, etc. — Improved lubrication; reduced breakage; reduction in scrap; deeper draws; less scratching; elimination of some annealing; less wear on dies.

Cold Extrusion — Improved lubrication; increased strength of parts; improved surface; reduction in load on press; greater dimensional accuracy; more uniform wall thickness; longer extrusions; elimination of some annealing; less corrosion.

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "GRANODRAW" AND ON YOUR OWN METAL PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

physics, and in the many biographical notes.

Each chapter includes a list of discussion questions designed to develop reasoning ability rather than memory alone. Definitions, defining equations, units, laws, and principles are concisely restated at the end of each chapter and arranged to provide a quick and systematic review.

In this edition, many of the chapters on electricity have been revised. The chapter on electronics has been largely rewritten to emphasize the conduction of electricity in gases and in vacuum. The section on twentieth-century physics has been expanded and revised to trace the historical development of our present ideas of atomic and nuclear physics.

Although calculus notation has been avoided in the body of the text, important derivations carried out by calculus methods are included in the appendix for the reader's benefit.

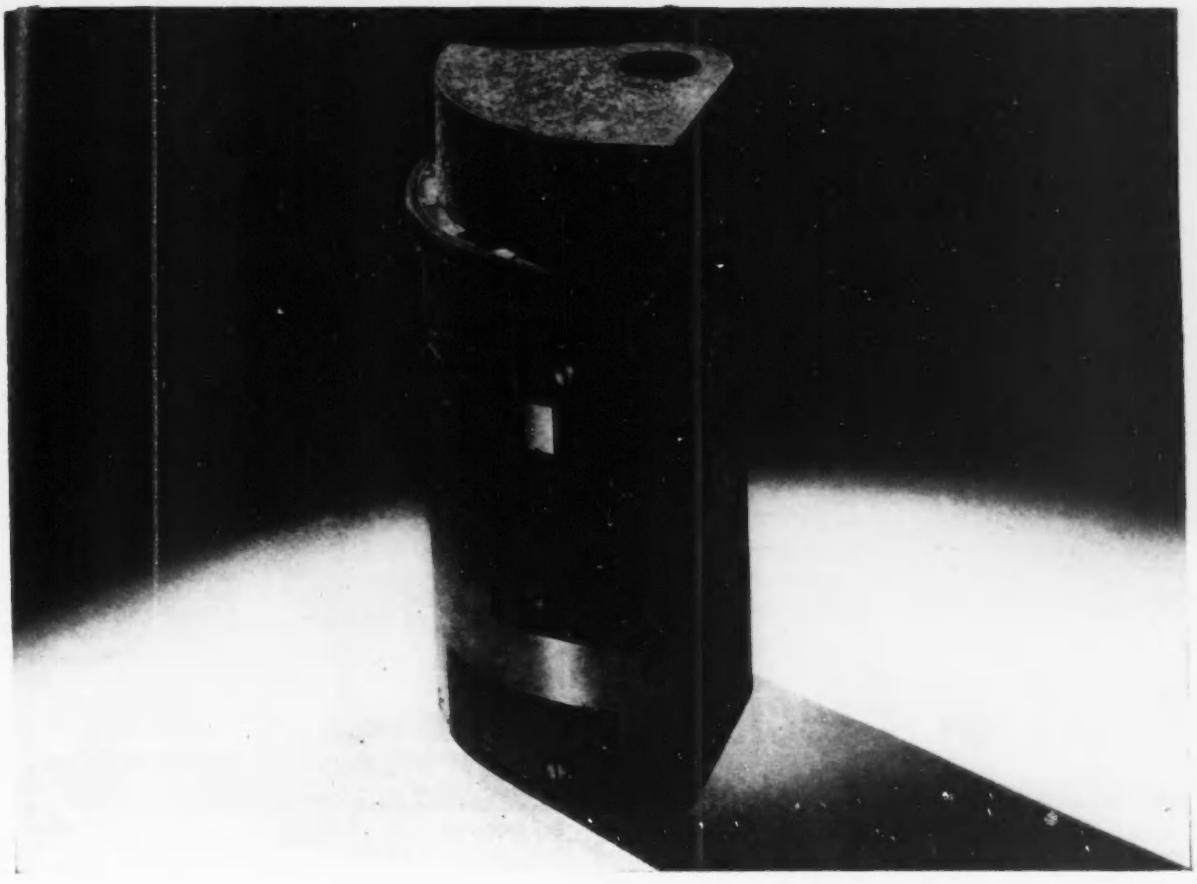
Receiver Troubleshooting And Repair

ALFRED A. GHIRARDI. 822 *pp*, 6 x 9 *in. Published by Rinehart Books, Inc., 232 Madison Avenue, New York 16, New York.* $6.

This book provides information necessary for recognizing, locating, and repairing defects in radio and television receivers. The style is clear and simple, and the language is practical and nonmathematical. Tables and charts are used throughout the book to present step-by-step procedures. Over 400 illustrations help explain what, how, when and where troubles are traced and repairs effected.

The book starts with a careful analysis of radio and TV components and the reasons for their failure in receiver circuits. Then follows an analysis of preliminary questions, observations and checks, static tests, dynamic tests, and the intelligent combination of all these methods into a practical and direct-approach servicing procedure. Special problems involved in servicing communications receivers, a-c/d-c receivers, battery-powered sets, and television receivers are covered in further chapters.

Realignment of AM, FM and TV receivers is given complete treatment, a separate chapter for each. The replacement problems for the most important types of receiver components are covered in detail. Finally, two chapters cover servicing problems connected with record changers and recorders, respectively.



A controller contact drum assembly, constructed of Celoron, Vulcanized Fibre and Brass.

HERE'S A DRUM THAT'S *HARD* TO BEAT!

Ever wonder how a Diesel locomotive's speeds are controlled from stand-still to full speed? The throttle lever turns this contact drum, actuating governor solenoid controls which in turn control the speed of the Diesel engines. The throttle has ten positions: stop, idle, and running speeds one to eight. Each running notch on the throttle controller increases the engine speed in increments of 75 r.p.m., from 275 r.p.m. at idle to 800 r.p.m. at full throttle. A leading Diesel locomotive manufacturer designed this mechanism which uses two C-D-F materials to do a job requiring unusual insulating and mechanical strengths.

The drum body is molded C-D-F Celoron, a macerated canvas-filled phenolic material. The special shape, a sector of a cylinder, is uniformly molded and is half the weight of aluminum . . . dimensionally stable . . . of superior electrical and mechanical strength. Eight and a half inches high, the drum has been drilled and broached; brass screws attach a cast brass contact surface, milled to give the desired contact arrangement.

Tough, flexible C-D-F Vulcanized Fibre is between the contacts, enabling the contact fingers to slide from the metal to the insulated surface without dipping into the space between the contacts. Fibre was specified because of its unusual arc extinguishing and non-tracking characteristics. Whenever a circuit is broken, the resulting arc is drawn out across the surface of one of the Vulcanized Fibre segments, thereby protecting the surface of the phenolic drum from the arc.

If you have an insulating problem, probably a C-D-F product is the answer. C-D-F manufactures and fabricates electrical insulation, laminated and molded plastics, Micabond and Teflon tapes and sheets. Sales offices are located in principal cities. Call your C-D-F sales engineer—he's a good man to know!

CDF

Continental-Diamond Fibre Company

GENERAL OFFICES
NEWARK 40, DELAWARE

Proof of Precision

that means tighter fastening!

See the unique multiple-spline socket in that large 1-inch Bristol Socket Screw.

You'll find this same exclusive Bristol feature (vital to *tighter* tightening) in every one of the 7,438 tiny No. 0 Bristol Socket Screws held in that 2 oz shot glass.

It takes precise machinery . . . painstaking effort . . . to make them that way. But it's worth it . . . to give you shock-resistant fasteners, precise enough to be used in electric razors, cameras, communications devices, instruments of all kinds.

The multiple-spline socket permits tightening beyond limit of ordinary screws . . . turns internal wrenching force into *rotary motion*, not expanding pressure. Hence, no bursting, no rounding out of socket walls—even in sizes down to No. 3, 2, 1, 0 wire size. *Result:* maximum resistance to vibration.

Other advantages: ideal for compact assemblies and hard-to-get-at fastening points. For disassembly, a reverse flick of wrench loosens the set.

Only BRISTOL *gives you the right socket screw for every application*

BRISTOL'S

Multiple-Spline and Hex Socket Screws...Cap and Set

SEND COUPON FOR FREE SAMPLES —also helpful bulletins on designing compact, tight assemblies.

The Bristol Company
Mill Supplies Division
121 Bristol Road, Waterbury 20, Conn.

Please send me free sample of Bristol's Multiple-Spline Screw and bulletins showing applications to:

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COMPANY_____
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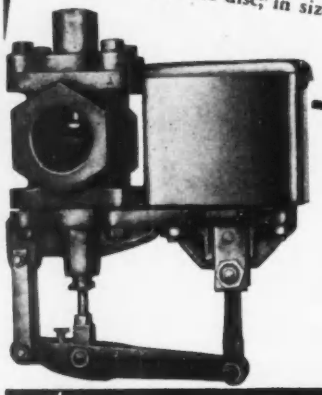
CITY_____ ZONE_____ STATE_____
Screw Sizes_____
Our problem is mainly_____ VIBRATION ☐
COMPACT DESIGN ☐ FREQUENT TAKE-APART ☐

JOHNSON Direct Acting Solenoid Valve — for 150 lbs. Differential Pressure . . .

You *can* get a solenoid valve that operates under differential pressures up to 150 lbs., temperatures to 400°F., *without pilot valves*. It ends the time lag and wiredrawing that come with slow opening —the danger of sticking that comes with auxiliary pistons. It offers unusual possibilities for all types of automatic, or remote, flow control. Johnson Solenoid Valves are available for normally closed or normally open service; with stainless steel valve and seat or Jenkins disc; in sizes from ½" to 3".

Write for Bulletin "V"

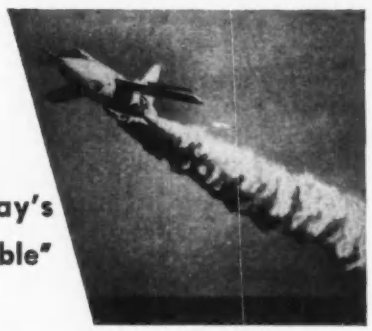


WHERE CAN YOU USE THIS AUTOMATIC VALVE?

- No pilot valves
- Temperatures to 400°F.
- Differential Pressures to 150 lbs.
- Immediate full flow
- Heavy duty construction

The Johnson Corporation

813 WOOD ST. THREE RIVERS, MICHIGAN



Yesterday's "impossible" designs

are being executed successfully with Micro Ground Miniature Ball Bearings

America's first and only fully *ground* miniature ball bearings, Micro makes possible design refinements unheard of only a few years ago. With 85 sizes and types from ⅜" down to ⅛" o.d. and in tolerance ranges of ABEC-5 and above, Micro bearings offer tremendous opportunities to minimize space, weight and friction and at the same time to retain high capacity. Yet Micro precision ground bearings actually cost less than comparable *unground* miniatures.

Write for Technical Bulletin No. 50

MICRO

New Hampshire Ball Bearings, Inc.

3 Main Street, Peterborough 1, N. H.

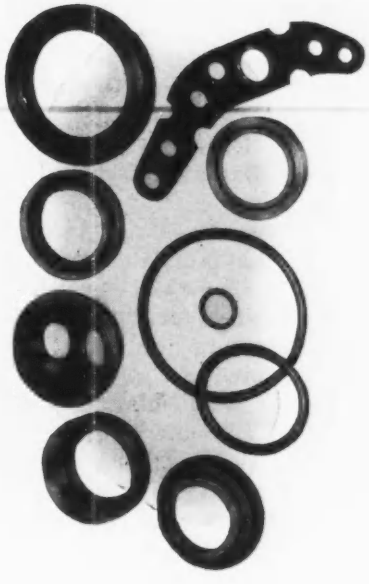
Meet William L. Harris

Superintendent

International Packings Corporation

Affiliated with Graton & Knight Company

Graduating with a B.S. Degree in Chemistry from Hamline University in St. Paul, Mr. Harris has devoted his entire career in the two fields of synthetic rubbers and leathers. As a scientist, the government called upon him as a technical adviser to supervise the GRS rubber program. As a production man, he has served as foreman, production manager, and ultimately as development manager for new and experimental work on mechanical packings and specialties. This background has ideally fitted him for his present job as Superintendent. He knows his materials and what each can do. Equally important he knows how to make these materials into efficient packings.



In this current series of advertisements we want you to meet these men. Their experience is yours to command.

There's practical know-how in the manufacture of packings

The type of packings, the material from which they are made, the treatment given that material are important. At G&K-INTERNATIONAL you'll find a wealth of experience on which to base a wise choice.

Equally important is how these packings are made — the step-by-step adherence to tolerances, both dimensional and physical; the proper sequence given to operations and treatments so as to obtain to the fullest those qualities that mean longer life and more efficient service; and, of course, modern machinery, skilled workmen and intelligent supervision all combined to produce those packings most economically. These production advantages are all yours when you specify G&K-INTERNATIONAL packings.

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Leather and synthetic packings

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GRATON & KNIGHT COMPANY
Worcester 4, Mass.

INTERNATIONAL PACKINGS CORPORATION
Bristol, New Hampshire

There's a helpful design tip in this use of S.S.WHITE flexible shafts

The S.S.White flexible shaft couples the trip odometer mechanism to the reset knob. The shaft makes it possible to place both the instrument and the knob wherever desirable both for appearance and for convenience. This extra freedom that S.S.White flexible shafts give in locating coupled parts is a mighty important advantage in designing any equipment.

The shafts will prove useful in many other ways. Their installation presents no problems — they can by-pass obstacles in their path — will operate around turns — are simple to connect — and require no alignment. Furthermore, they are designed to provide smooth, positive operation at all times.

There's no simpler way to transmit power or control in paths other than straight lines. It may pay you to check your present methods of coupling and see if you can't possibly do it better, faster, easier and more economically with S.S.White flexible shafts.

Send for This 256-Page Flexible Shaft Handbook

Complete, authoritative information on flexible shaft construction, selection and application. Copy sent free if you write us direct on your business letterhead, giving your title. There's no obligation.

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Applications for gray iron in your products can be greatly expanded if surfaces of castings can meet a wide variety of finish specifications. Since gray iron is in many respects one of the most economical of base metals, careful consideration of applicable finishes is worthwhile.

This Special Editorial Report by Charles O. Burgess, Technical Director, Gray Iron Founders' Society, will serve as an invaluable guide for organic and chemical finishes for the manufacturers of gray iron products.

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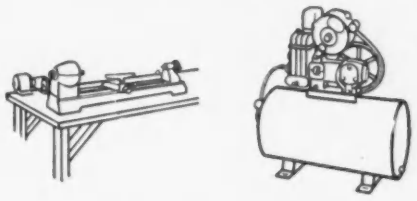
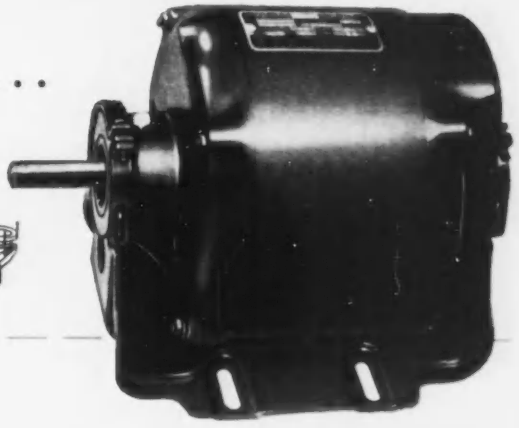
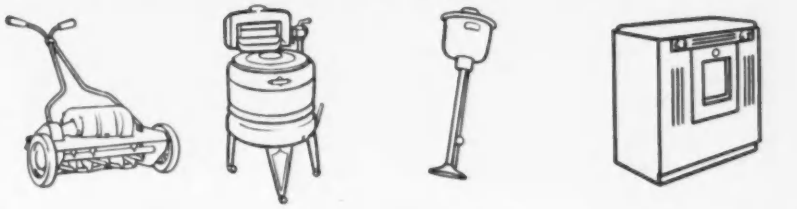




or **UNCOMMON** applications . . .



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DELCO MOTOR

Built for the Job!

Wherever fractional motors are needed —for small power tools, pumps, compressors, or any of hundreds of applications—you'll be *sure* of satisfactory performance by using Delco motors for the job.

From every standpoint, electrical and mechanical, Delco motors are *engineered and built* to deliver peak performance. And the way Delco motors *stand up* on the job has created a reputation for dependability — *Delco dependability* — that's unmatched in the field.

Get the data on Delco motors—and on how they best fit your needs—now. Write Delco Products, Dayton, Ohio, or the nearest sales office.

DELCO FEATURES MAKE DELCO FINEST

- Aluminum rotor conductors, end rings and fan blades.
- Oversize steel-backed tin babbitt sleeve bearings.
- Varnish-dipped and baked motor windings.
- Resilient rings of special oil-resistant material.
- Large oil reservoirs cast integrally with end-frames.
- Exclusive Delco Thermotron for automatic motor protection.

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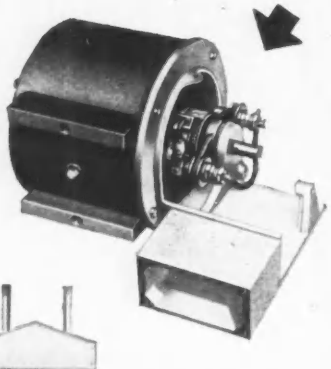
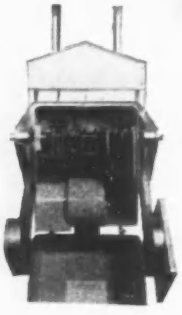
THAT'S THE KIND WE WANT

for instance...

Transport Products Corp. of Louisville, Kentucky, needed a motor to operate automatic crossing gates. The motor had to be extremely efficient because it operates from high cost storage battery current. For obvious reasons it needed to be fool-proof and it had to be tough because the lowering gate forces the motor to operate in reverse to generate current within itself. This brakes the arm's descent.

HERE IS THE WESCHE MOTOR THAT GETS THE JOB DONE!





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Your special motor requirement is probably far removed from railroad crossings but if it's out of the ordinary, Wesche engineers are ready to come up with the motor to do, not a job...but *the* job.

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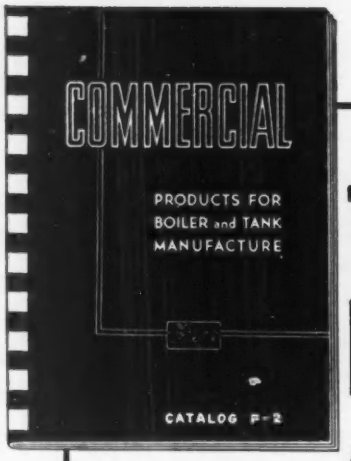
1624 Vine Street • Cincinnati 10, Ohio



TANK HEAD *Catalog by* "COMMERCIAL"

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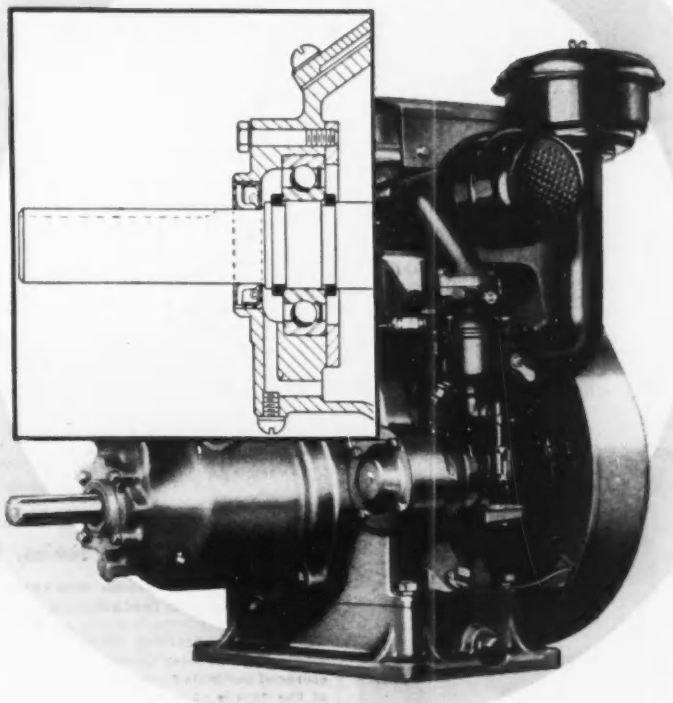
EARLE GEARS

It's good business to do business with EARLE

SAVE wherever you can!

RETAINING RINGS will help



These inexpensive, efficient artificial shoulders save metal and money on Wisconsin air cooled heavy duty engines.

And in addition to saving money and metal, retaining rings save many costly hours in assembly time. Instead of the former wasteful practice of cutting down large shafts, you can redesign to groove smaller shafts and use these high grade steel rings. In your housings, too, rings will save money and improve your products, your machines and your profits.

Every product—metal, wooden or plastic—and every machine should be examined now to see where shoulders and collars can be redesigned to effect great savings by the use of steel retaining rings.

Let us show you how they can do an efficient job for you on your shafts or in your housings.

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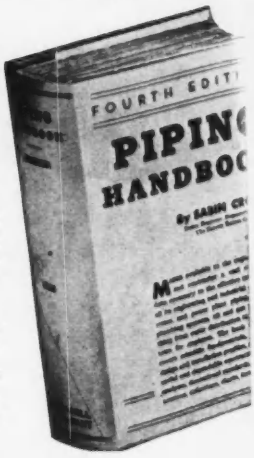
Complete, comprehensive guide to piping design and application

—The data and methods you need for solving every piping problem



HERE is an indispensable tool for the engineer, contractor, and designer, the famous PIPING HANDBOOK. This vast compilation of data and methods for most effective use of piping puts at your fingertips all the principles that influence the design, construction and use of piping systems. *Any* fact, on any phase of piping practice, is here in clear, dependable, accessible form.

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By SABIN CROCKER

Senior Engineer, Engineering Division, The Detroit Edison Company

1376 pages, 4½ x 7½, 334 illustrations, 329 tables, $8.50

Solve your piping problems with the help of this practical handbook packed with piping fundamentals, materials and techniques . . . and authoritative information you need on codes, dimensional standards, materials specifications, construction details, cost estimating, etc. It shows you the best types of apparatus for each job . . . brings you scores of methods for using equipment for best results, helpful analyses of the details of each job, easy-to-follow explanations of every phase of piping from start to finish.

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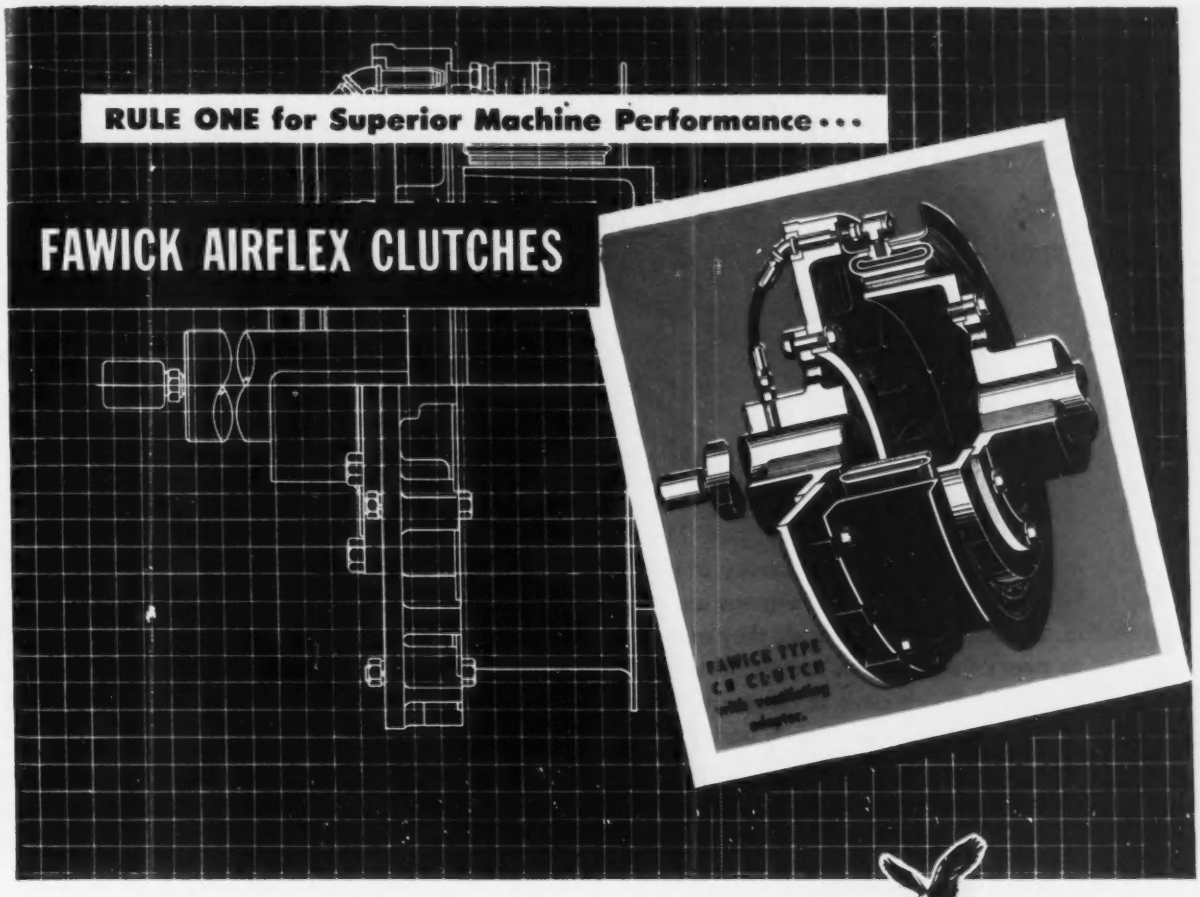
FAWICK AIRFLEX CLUTCHES



RULE ONE in designing and engineering high-efficiency machines is to insure peak performance of the finished equipment by specifying FAWICK AIRFLEX CLUTCHES AND BRAKES. Their compact, rugged design and simplicity not only make them easily adaptable in all types of installations but also provide top-efficiency performance under the most severe operating conditions.

PLUS operating advantages—Instant full power transmission, shock-free engagement, cooler friction surfaces, and low maintenance are "built-in" features of FAWICK AIRFLEX units.

The high-efficiency-performance records of increasing thousands of Fawick-equipped machines in industrial production offer proof of the operating results obtained with FAWICK.

Insure top performance for your design with superior FAWICK AIRFLEX CLUTCHES AND BRAKES.

The FAWICK AIRFLEX COMPANY, Inc.
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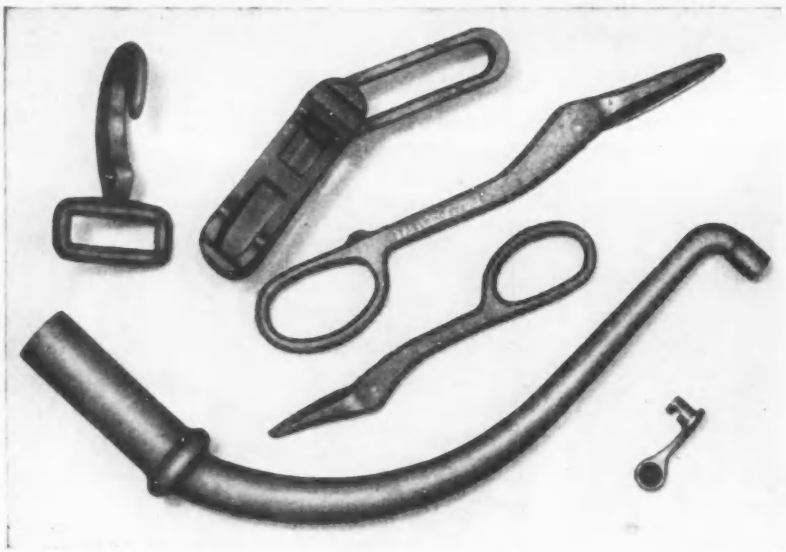
INDUSTRIAL CLUTCHES AND BRAKES

FAWICK Airflex
INDUSTRIAL CLUTCHES AND BRAKES WILL BRING YOU:

- **COOLER CLUTCH OPERATION**
  Fawick design provides maximum ventilation.
- **CUSHIONED DEPENDABLE ACTION**
  Rubber and cord construction of air tube reduces shaft vibrations and absorbs operating shocks.
- **SELF-ADJUSTMENT**
  Air tube automatically compensates for friction shoe wear and insures complete engagement at all times.
- **LOW MAINTENANCE**
  Elimination of mechanical linkage, adjustments, and lubrication provide unparalleled low maintenance costs.

For further information on Fawick Industrial Clutch and Brake Units, write to the Main Office, Cleveland, Ohio, for Bulletin ML-22.



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RITCO

DROP FORGINGS

For maximum strength and accuracy of metal parts, Ritco Bright Finish Drop Forgings are outstanding. Smooth and free of flash, they are produced in steel or non-ferrous metals, in weights from ¼ lb. to 15 lbs. It pays to remember Ritco for drop forgings, special fasteners, and regular and heavy head finished body bolts . . . also for machining and grinding.

Send blueprints for free estimates. Rhode Island Tool Company, 148 West River St., Providence 1, Rhode Island.

Exclusive New England Representatives for Cleveland Cap Screws

★ SERVING AMERICAN INDUSTRY SINCE 1834 ★

IDEA FOR DESIGN ENGINEERS:

At last—a DETACHABLE Line Cord that eliminates trailing cords on your products as they go down the line

—just pop a simple terminal socket into a ¾" hole on your equipment, solder AC connections to terminal socket just as with your other inside soldering. Eliminates all special planning, training, grommets, Underwriter's knots, etc. Assembly works out cheaper than permanent cords.

Sure-grip Plug is self-piloting
Any-length cord, molded and Alden-anchored so plugs can be pulled out by grasping cord.
Socket fits ¾" hole. Simply push in. Generous solder tabs.

Thus . . . when your equipment reaches the end of your production line, simply plug in the beautiful color-matching Detachable Line Cord, that gives your user a choice of just-right length, and adds the final touch of Quality and Convenience that hallmarks your product as deluxe.

ELIMINATE THIS:

SEND $1.00 FOR "LABORATORY WORK KIT #16" GIVING YOUR MODEL SHOP CORDIZING ELEMENTS FOR A VARIETY OF REQUIREMENTS.

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NA-ALO ALDEN PRODUCTS COMPANY

FOR YOUR PANEL DIALCO

A NOVEL and UNIQUE CIRCUIT INDICATOR

DESIGNED FOR NE-51 NEON LAMP
For 110 or 220 volt circuits
The required resistor is an integral part of this assembly —"built-in."
RUGGED DEPENDABLE LOW IN COST

PATENTED: No. 2,421,321; Cat. No. 521308-997

WILL *YOU* TRY A SAMPLE?

Write on your company letterhead. We will act at once. *No charge, of course.*

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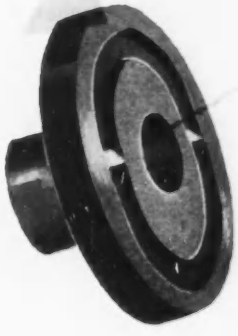
The DIAL LIGHT COMPANY of AMERICA
900 BROADWAY, NEW YORK 3, N. Y. SPRING 7-1300

How would you produce this part?



The part illustrated was made by The Wel-Met Co., Kent, Ohio

It's a small part for a Dictaphone Time-Master Dictating Machine . . . Dictaphone engineers tried machining the figure-8 cam groove and inserting two triangular rise-points. Too costly! Then they tried casting in brass by the lost wax method. Unsatisfactory groove!

The irregular contours, changing radii, the rise-points in the cam groove, pointed to powder metallurgy as the solution of these complex difficulties.

The precision of this method is such that machining or finishing operations are often eliminated.

Tolerances as low as ±.003" are easily held; on some parts as close as ±.001". Production rates run as high as 50,000 per hour per press.

The pressing and sintering processes create novel alloys, as of copper with steel or copper with carbon . . . permit the combining of oil and metal to give long self-lubricating bearing life . . . cut costs of many parts to a fraction of what they would be by machining, casting, forging, stamping.

Stokes engineers . . . designers and builders of the presses on which powder metal parts are made . . . will gladly consult with you on the suitability of your parts for powder metal production . . . or on their re-design to adapt them to this money-saving method.

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F. J. STOKES MACHINE COMPANY, 5500 TABOR ROAD, PHILADELPHIA 20, PA.

$700 saved . . .

more efficiency gained

with

STOW flexible shafting

courtesy IOWA MFG. CO.

That's the experience of the IOWA MFG. CO., manufacturers of this super-tandem crushing plant which employs a 1¼" STOW power drive shaft, operating at 800 RPM. A centrifugal clutch relieves sudden starting loads. Use of the flexible shaft as shown permits a swing of up to 90 degrees either side of the center line.

This is another fine example proving the efficiency, the practicability of STOW flexible shafting.

Why not consult with STOW engineers on your next power transmission problem. You'll find that Stow flexible shafting can really do a job for you!

***Write today** for this free bulletin 515 and Torque Calculator, containing complete data on STOW flexible shafting. No obligation, of course.*

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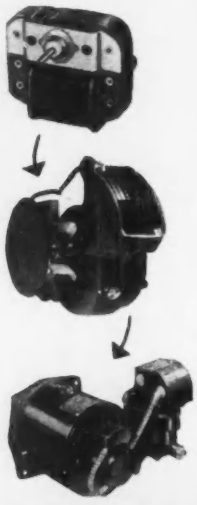
WITH BARCOL MOTORS



Like the side-show fire-eater, who must blow just right to keep his spectacular flame going, an oil burner requires the right amount of air to keep its flame correct and efficient. Breese Burners, Inc., of Santa Fe, New Mexico, make this "Draftbooster" — a fan, driven by a Type DYAB Barcol Motor — to provide a positive, and adjustable, supply of air for vaporizing type oil burners. The "Draftbooster" is used on burners for furnaces, space heaters, cooking ranges, and floor furnaces. A series rheostat can be used to govern the motor speed so as to obtain proper proportion of air to oil over a wide range of heat outputs. Write for Barcol Motor Bulletin F-3168-1 for data.

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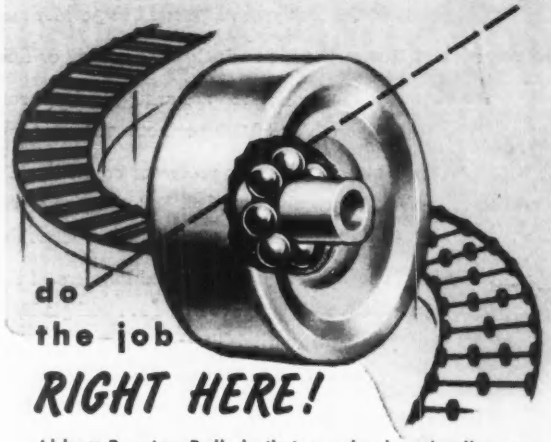

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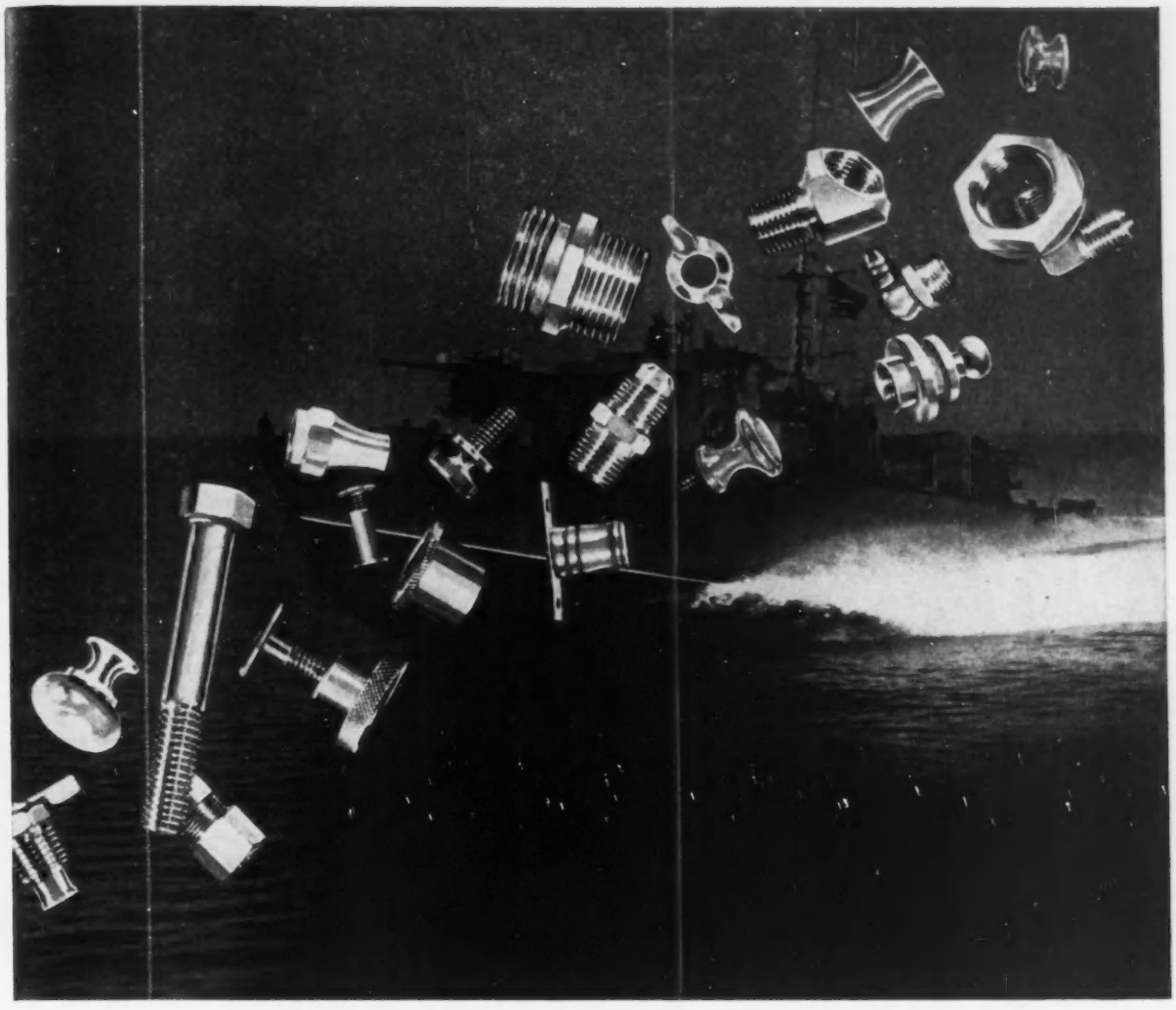

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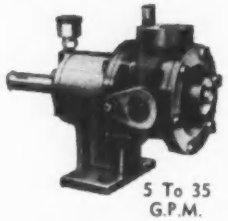

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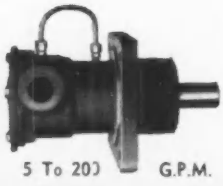

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PRODUCT ENGINEERING

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The Marsh Electric Dial-Taper is a very efficient, compact unit. A turn of the telephone-like dial on the face of the machine produces, in a split second, the desired piece of tape accurately measured, cut-off and moistened with warm water.

When designing the unit, the Marsh Stencil Machine Co. was faced with the problem of finding a standard motor that was compact enough to fit a limited space, yet capable of continuous start and stop operation for an 8 hour day, pulling a roll of heavy tape of variable weight.

Design and space limitations dictated that a gear be mounted directly on the drive shaft of the motor. Therefore, to eliminate all possible end-play and run-out, and to insure proper meshing of gears, the motor (Bodine Type NCI-33) selected for the application had to have a very rigid frame and close tolerances.

Before deciding on a motor for your application, it will pay you to investigate the possibility of using a standard motor. Bodine's wide variety of standard motors—over 3500 in all types and ratings (1/2000 to 1/6 hp)—might permit you to use a standard motor in place of a more costly special type. And when special motors are necessary, this wide selection of standard motors tend to keep the number of cost-increasing modifications to a minimum.

Over 3500 Standard Bodine Motors (1/2000 to 1/6 hp)

Built-in spur gear speed reducer motor. Especially designed for instruments and control apparatus.

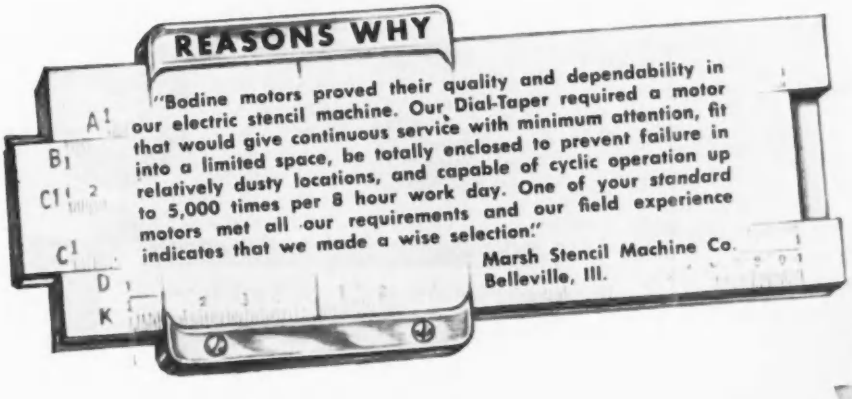
Ball bearing motor with terminal box and shield for metal working machines and other industrial applications requiring conduit connection.

A compact, flange-mounted double worm gear reducer for panel rheostats, magnetic separators and similar applications.

Only 3⅜" in diameter. Used in oxygen tent blowers, centrifuges, commutator undercutters, laboratory pipette shakers and similar devices.

A single reduction, right angle worm gear reducer for proportioning pumps, optical comparators, chime strikers, etc.

THE POWER BEHIND THE LEADING PRODUCTS


REASONS WHY
"Bodine motors proved their quality and dependability in our electric stencil machine. Our Dial-Taper required a motor that would give continuous service with minimum attention, fit into a limited space, be totally enclosed to prevent failure in relatively dusty locations, and capable of cyclic operation up to 5,000 times per 8 hour work day. One of your standard motors met all our requirements and our field experience indicates that we made a wise selection!"
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Belleville, Ill.

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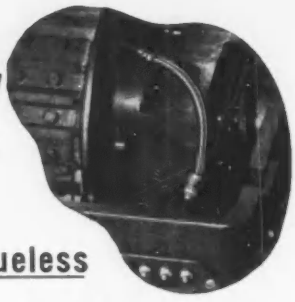
oilproof

and have fatigueless

flexibility...



USE

RESISTOFLEX HOSE ASSEMBLIES

There's nothing to fatigue in Resistoflex hose – not the synthetic rubber jacket, the high grade yarn braiding, nor the compar tube.

And no gumming, eroding or swelling from oil either. For the compar tube is impervious to water-insoluble oils and compounds. The compar tube also adds more than necessary strength for medium pressures and shock loads in hydraulic systems.

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For out of the ordinary engineering with synthetics

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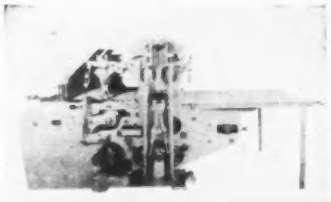
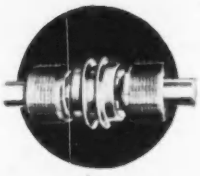
THE **RUTHMAN** MACHINERY CO.

This Large Machine Has a





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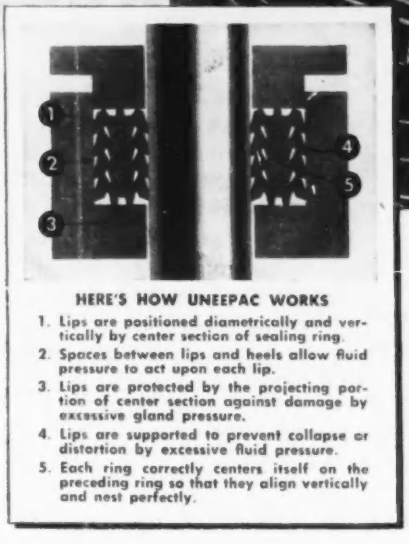

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5. Each ring correctly centers itself on the preceding ring so that they align vertically and nest perfectly.

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YOU CAN SAVE ASSEMBLY TIME by using Uneepac because its unique design practically eliminates packing installation troubles.

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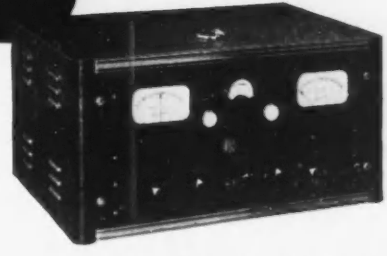
The JK FD-12 monitors any four frequencies anywhere between 25 mc and 175 mc, checking both frequency deviation and amount of modulation. A truly precise instrument for communication systems!



When used for different bands, plug-in type antenna coils provided. Crystal accuracy guaranteed to be ± .0015% over range of 15° to 50° C. Meets or exceeds FCC requirements.

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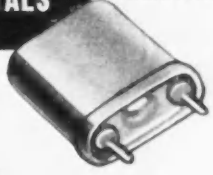

Well known to every communications man is the famous JK Stabilized H-17, with a frequency range of 200 kc to 100 mc. But this is just one crystal in the JK line. Write for complete crystal catalog!

ALSO manufacturer of the James Knights Frequency Standard.

THE JAMES KNIGHTS COMPANY

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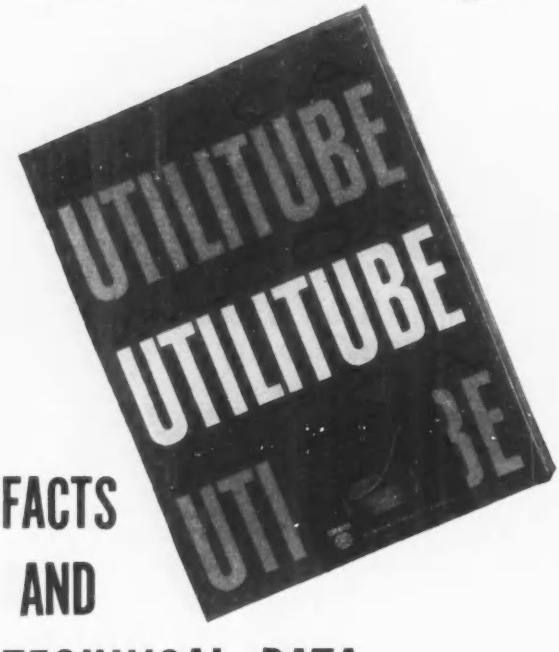

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Send for this new booklet describing Alcoa's new aluminum coiled tube—UTILITUBE. Alcoa UTILITUBE is designed for instrumentation, fuel, air and lubrication applications. It is easier to form, flare and bend than annealed copper. It will save you up to 40% on tube costs—gives you 3 times more feet per pound. It comes in standard 50- and 100-foot lengths and in economical long lengths up to 1,000 feet in some sizes. And aluminum fittings are now available from leading tube fitting distributors. Write:

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ALCOA

NEW SKINNER SOLENOID VALVE

EXPLOSION PROOF TYPE X5

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SKINNER ELECTRIC VALVE DIV.
THE SKINNER CHUCK COMPANY
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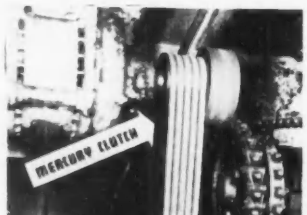


A Mercury Automatic Clutch installed on a Textile Gig

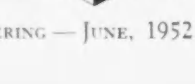
The Mercury Automatic Clutch is the perfect solution to prevailing power transmission problems on textile machinery . . . and wherever an electric motor or gasoline engine provides power for machinery or equipment.

4 REASONS WHY A MERCURY AUTOMATIC CLUTCH IS A GOOD INVESTMENT

- ***UTILIZATION OF MAXIMUM MOTOR TORQUE***
- ***PROVEN DEPENDABILITY***
- ***SAVING OF MOTOR COST***
- ***INCREASED PRODUCTION***

Get the full story on the Mercury Clutch. Write today for Mercury Catalog PR-9.

MERCURY CLUTCH DIVISION
AUTOMATIC STEEL PRODUCTS, INC.
CANTON 6, OHIO



Put FORCE behind your vibration testing

...more than 2500 pounds of it with this big MB exciter

POWER AND ENDURANCE feature this new MB Model C25 Vibration Exciter—today's largest and most dependable electromagnetic shaker.

It has already proved its heavy-duty capacity in a number of important military vibration testing applications. In frequencies from 3 to 500 cps, it easily develops required forces to produce accelerations of 15g with 100 lb table load or 20g with 60 lb table load, for example.

Like all MB Exciters, Model C25 Shaker provides easy, accurate, continuous control of force and frequency. It allows "scanning" for response to vibration of parts under test. Electrically interlocking controls assure trouble-free operation. Automatic cycling control available to meet specifications of MIL-E-5272.

Vibration testing shakes out troubles before they start. It's not only a "must" for much military equipment, but also a good idea for *any* product. If you'd like to know more about it, why not contact "headquarters" for vibration engineering—MB! You'll find the help and advice you're seeking.

APPROVED MOUNT FOR ISOLATING VIBRATION

This Type 17 MB Vibration Isolator incorporates a principle first achieved by MB in mountings. It has equal spring rates in all directions in order to isolate all modes of motion with equal efficiency. Available for loads from 0.5 to 100 lbs to meet MIL-I-5432 (AN-I-16a) specification on vibration isolation. Write Dept. 6 for details.

MORE DETAILS

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Product designers who specify ***Heli-Coil**** Screw Thread Inserts for threaded assemblies get full protection against wear and tear, particularly in light metals. These inserts add vital strength to all tapped threads . . . prevent stripping from high torque or tension; prevent corrosion, galling and seizing . . . and they *completely* eliminate thread wear caused by repeated disassembly and re-assembly.

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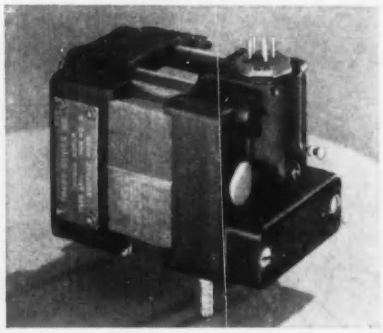
Linear Precision Actuator



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Type 35
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NATURAL FREQUENCY: > 400 cps
WEIGHT: 1 lb.
STALLED FORCE OUTPUT: 5 lbs.

➡ *Write for Bulletin 35* ⬅

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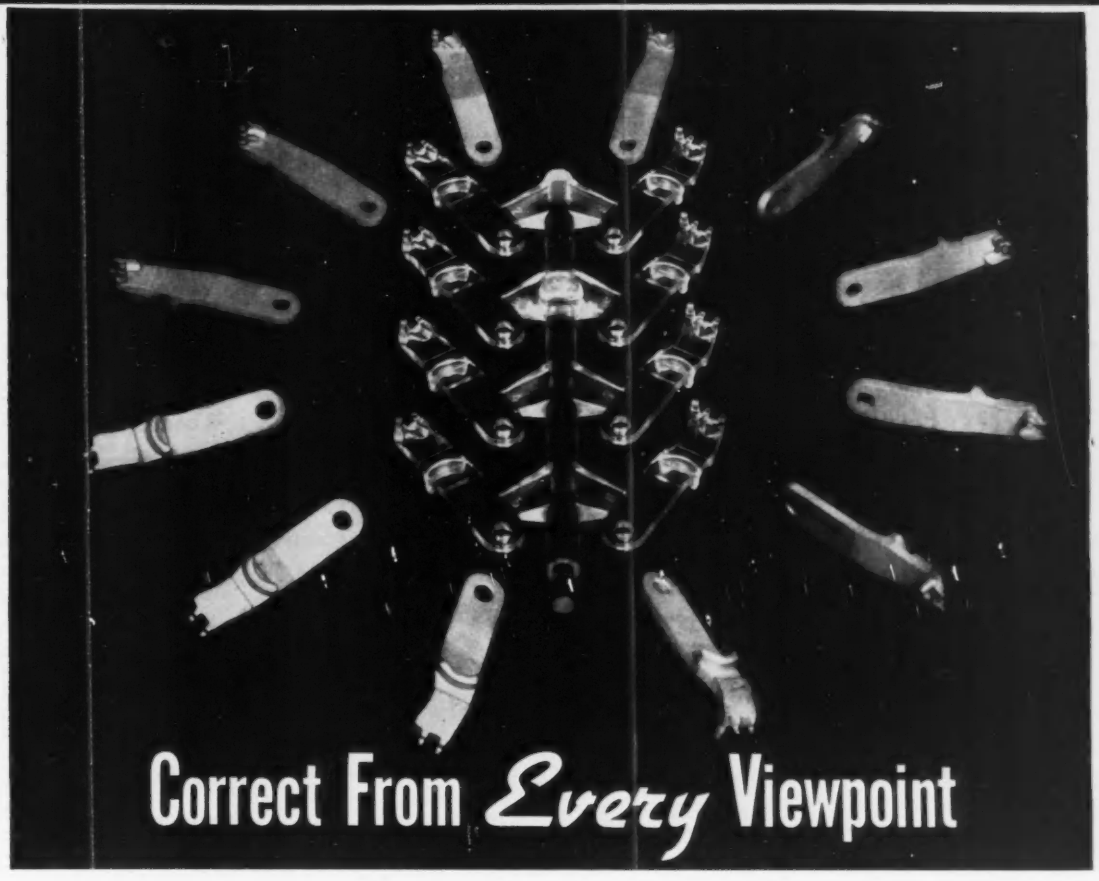

This Precision Casting is an accessory used in connection with the Garand M-1 Rifle. Misco is producing the part in hundreds of thousands for K. R. Wilson, Buffalo, N. Y., manufacturers of automotive service tools. Molded in clusters from plastic patterns, castings are poured in alloy steel of carefully controlled analysis for strength, toughness and resistance to wear. Production is rapid and economical, and due to the "as cast" accuracy of Misco Precision Castings, there is no machine work of any kind.

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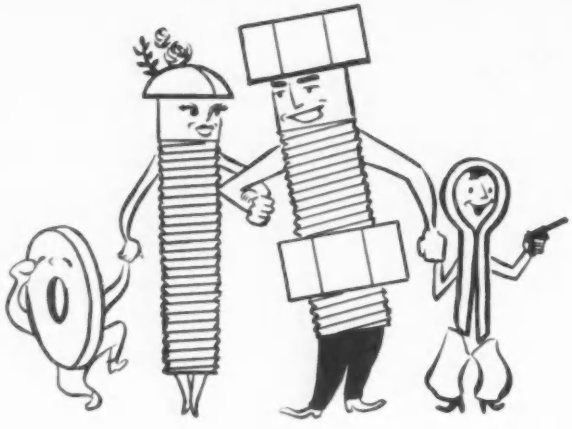

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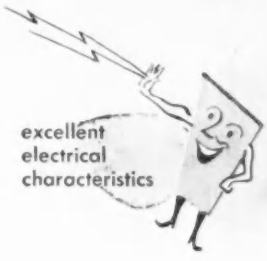
PRODUCT ENGINEERING

Duroid 800



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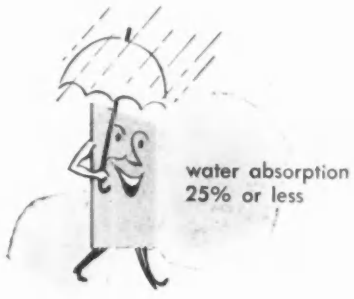
LOWEST IN COST (BY SHEET AREA) OF MATERIALS LISTED BY UNDERWRITERS LABORATORIES FOR "SOLE SUPPORT OF CURRENT CARRYING PARTS."



Users of DUROID 800 are pleasantly surprised with the excellent electrical characteristics and all-around capabilities of this new, unique fibrous material.

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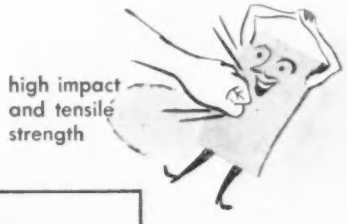

It will take riveting and stand up under the restraint of fasteners without warping. It retains its high dielectric strengths in the presence of moisture and actually increases in physical strength when wet.

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CORPORATION
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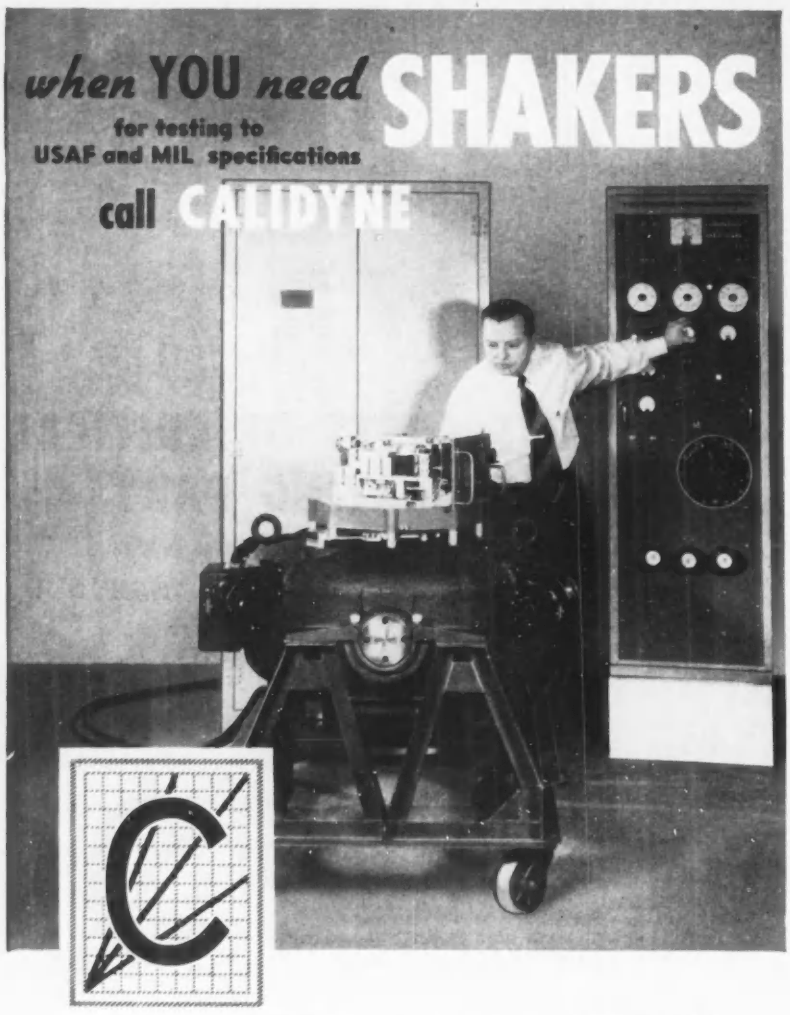

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Westinghouse has given its cooler a wardrobe of Spongex cellular rubber. Exposed cold surfaces—tubing, valves, even the waste water drain—are covered by custom molded Spongex parts. These Spongex parts not only prevent condensation but their insulating qualities increase refrigerating efficiency. For this cooler, Spongex means a longer, better, more efficient life.

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4. Regulator valve cap—
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5. Water valve cap—
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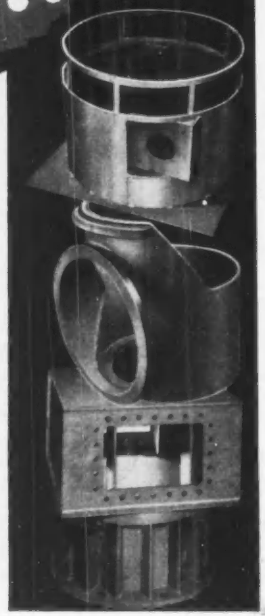

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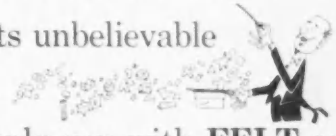

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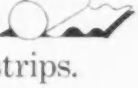

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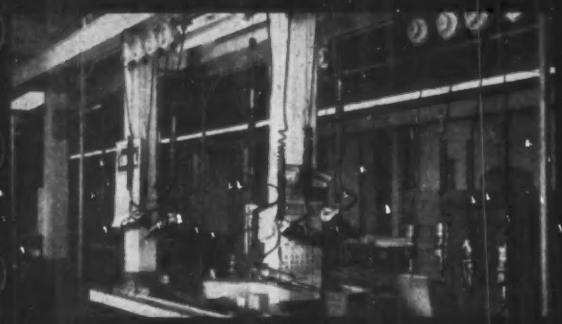

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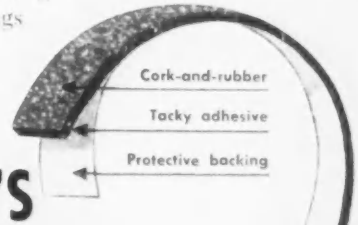

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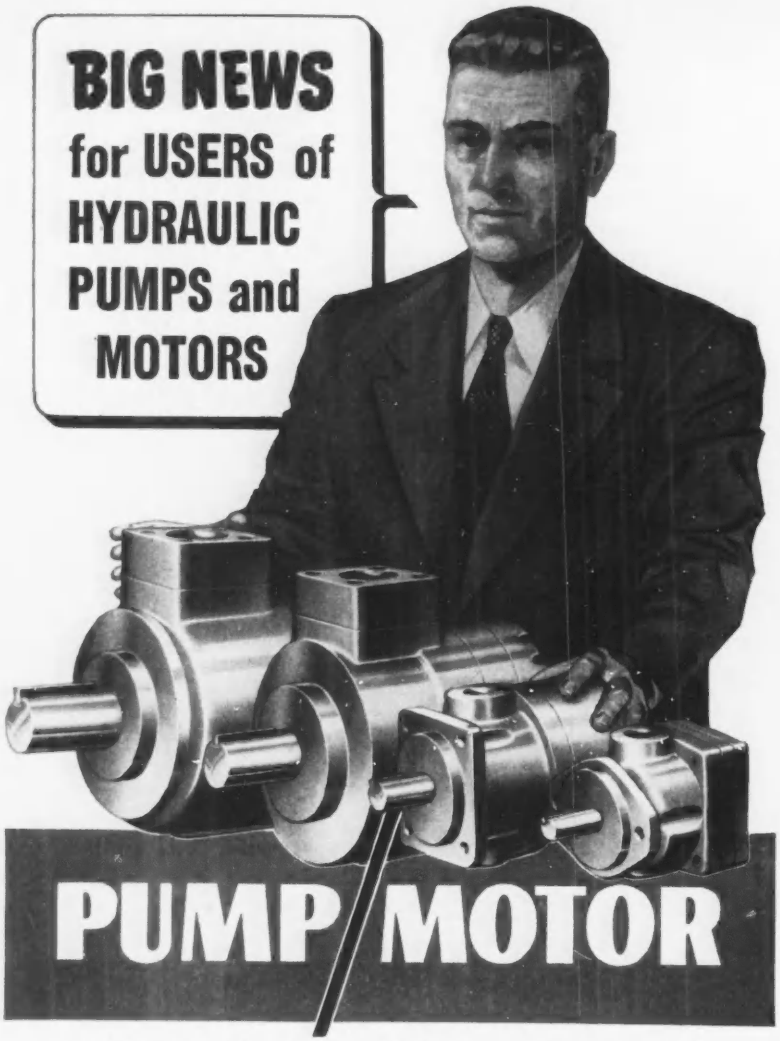

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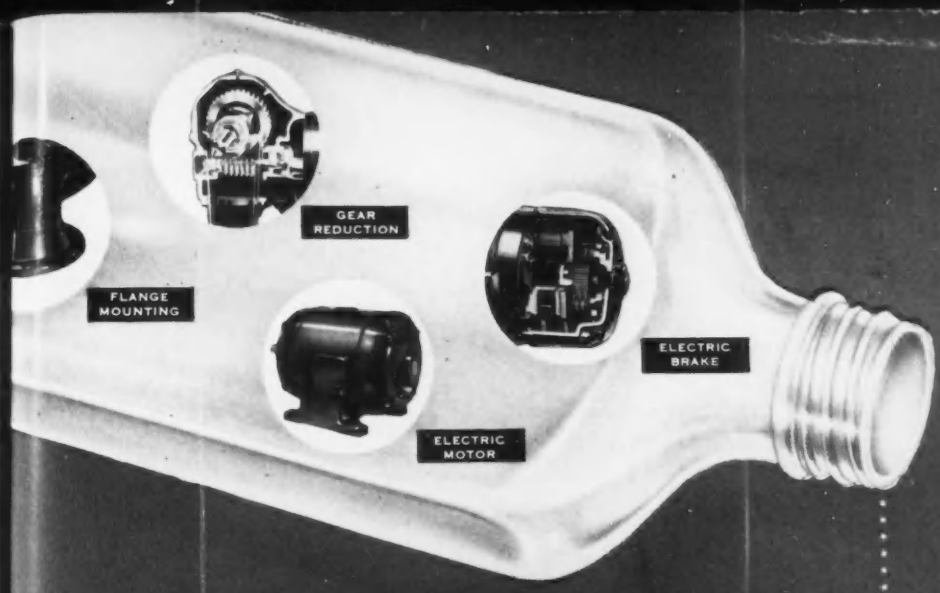

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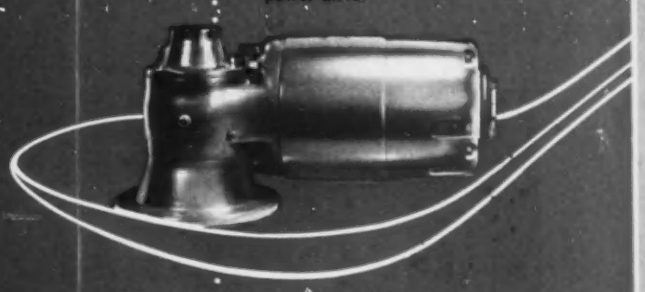

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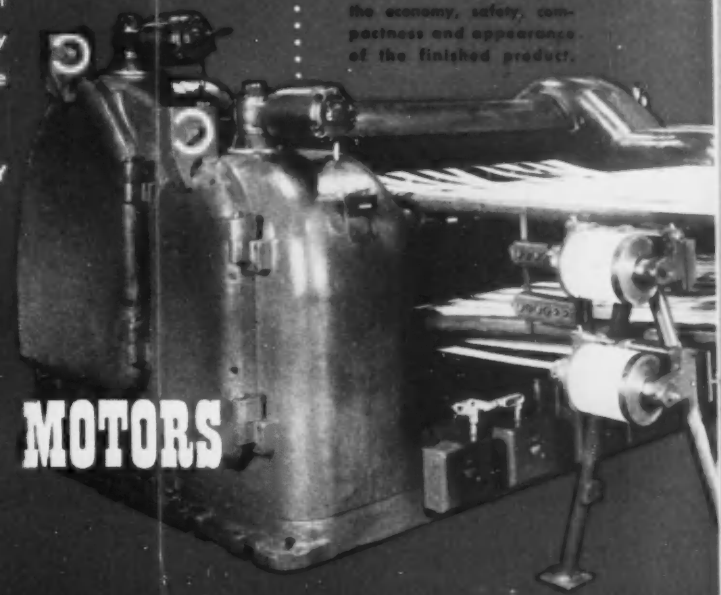

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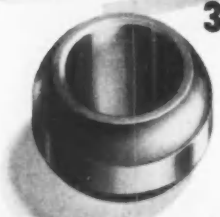

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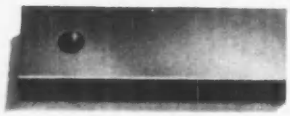

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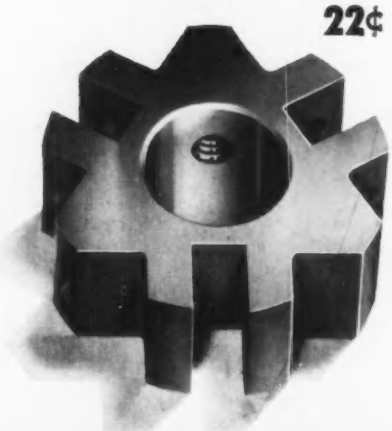

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